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L. G. KULKARNI, B.Ag., Ph.D.,

CENTRAL FOOD TECHNOLOGICAL RESEARCH INSTITUTE * MYSORE. *
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# Foreword

At its meeting held on the 22nd October 1955, the Indian Central Oilseeds Committee decided to bring out a series of monographs on oilseed crops. Seven monographs on Rape-Mustard, Castor, Niger, Safflower, Groundnut, Linseed and Sesamum were programmed and each one was assigned to a specialist on the subject. The present monograph on Castor was assigned to Dr. L. G. Kulkarni, who was till recently the Oilseed Specialist of the Andhra Pradesh Government.

Castor is an important commercial crop, as India is the second largest producer in the world. The average production during the quinquennium 1951-1956 was about 1,12,200 tons, representing 27 per cent of the world production. Andhra Pradesh has the largest area under Castor, the quinquennial average having been 9,10,400 acres, out of the total Indian acreage of 13,93,000, representing 65 per cent. Bombay takes the second rank and Mysore the third. In production also, Andhra Pradesh occupies the first rank, the quinquennial average having been 61,400 tons out of 1,12,200 tons, representing 55 per cent.

The average annual production of castor seed in India during the First Five-Year Plan was estimated at 1,12,200 tons, 94 per cent of which is utilised for oil extraction, while the remaining 6 per cent is used for seed purposes. About 98 per cent of castor oil is used for industrial purposes and about 2 per cent for non-edible domestic purposes, such as, toilet, soap, etc. Among the industrial uses of castor oil, may be mentioned lubrication, sulphonation, dehydration, manufacture of sulpho-recinoleate plasticizer, recinolyl alcohol and medicine.

In addition to these uses within the country, castor oil has also a great export value in earning foreign exchange. During the last year of the First Five-Year Plan, about 39,000 tons of castor oil valued at Rs. 4,09,000 was exported.

The importance of castor in the agricultural economy of India is recognised and it is also felt that there is very great need for stepping up its production. I hope the present monograph will be useful to the research and extension workers of castor-growing States. All available information on this crop has been compiled by the author who has considerable experience of this crop.

Dr. R. S. Vasudeva has written Chapter No. XII which deals with the "Diseases of Castor," while Dr. E. S. Narayanan has contributed the Chapter No. XIII on "Insect Pests of Castor."

Dr. K. C. Naik assisted by Messrs. M. Bhavanishanker Rao and T. R. Narayanan, scrutinised the manuscript as Technical Editor.

Dr. R. Sankaran, Secretary of the Indian Central Oilseeds Committee, has taken considerable interest in the production of this monograph and I am glad to say that it is due to his zeal and enthusiasm that the series of monographs, of which the present one is the fourth to be published, is being brought out in an attractive form.

M. S. RANDHAWA, D.Sc., F.N.I., I.C.S.
Vice-President, Indian Council of Agricultural Research,
Additional Secretary to the Government of India,
Ministry of Food and Agriculture (Department of Agriculture)
and
President, Indian Central Oilseeds Committee.

New Delhi,
3rd February, 1959.

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CHAPTER I

# HISTORY AND ORIGIN

Varied opinions are held regarding the exact land of origin of the castor plant. Hooker[65] holds the view that though castor is cultivated throughout India, yet it is indigenous to Africa. M. De Candolle[26] also holds a similar view. But Fluckiger and Hanbury[49] affirm that it is native to India. They hold this view mainly on the basis of knowledge of the medicinal uses of this plant as found in Sanskrit literature. Bentley and Trimen, as quoted by Watt[152] also believe that castor is native to India. Watt[152] in his extensive tours of India found some evidence only at the foot of Himalayas to show that castor is a native of India. He therefore believes that it may have originated in India as well as in Africa. Hindus have known castor oil from very remote periods. This oil has been mentioned in *Susruta Ayurveda*, one of the oldest works on *Ayurveda*. It is therefore possible that castor has originated both in India and Africa.

*Scientific Names*

Latin :—*Ricinus communis* Linn. F. Br. Ind. V. 457

French :—*Huile de castor, Ricin de palma* Christi

German :—*Ricinus semenol*

*Local Names*

Hindi :—*Erand, Arand*

Bengali :—*Bherenda*

Assamese :—*Eri, Era gatch*

Nepalese :—*Areta, Alha*

Bihari :—*Aurar, Anda*

Oriya :—*Gab*

Rajastani :—*Arend*

Marathi :—*Erandi*

Gujarathi :—*Diveligo, Diveli*

Tamil :—*Amanakku, Kottamuthu*

Telugu :—*Amadam, Amdi*

Kanarese :—*Haralu*

Malayalam :—*Ayanakku*

Sanskrit :—*Rakt erand, Vatahari*

Persian :—*Bedangir*

Chinese :—*Pi-ma*

Sumatra :—*Farak*

Egyptian :—*Kiki*

Ancient Greek :—*Kiki, KPOTWY.*

CHAPTER II

# DISTRIBUTION, AREA AND PRODUCTION

The world area and production statistics for castor seed are fluctuating every year. The main castor seed producing countries are Brazil, India, the U.S.S.R., Manchukuo and Argentina. Other countries growing castor include Indonesia (Java and Madura), the Philippines, Indo-China, Iran, Syria, Madagascar, Angola, French-Morocco, Mozambique, Dahomey, Italy, Rumania and Yugoslavia. During the second world war (1939-1945) the crop was also developed in Mexico and Japan.

Castor cultivation in India is very old indeed. In recent times castor seed is exported from India. Since 1914-18, the area under castor has varied from 1 to $1\frac{1}{2}$ million acres and production from 100,000 to 150,000 tons.

In Manchukuo the crop is grown from very old times. In 1933, 16,000 tons of castor were exported from Manchukuo and in 1934-38 an average of 23,000 tons per year.

Castor cultivation has developed in Brazil, the U.S.S.R., and Argentina only after the 1914-18 war. In Brazil the production for 1940 was estimated at 100,000 tons and in 1943, at 246,000 tons. There is no systematic cultivation in Brazil. The plants grow wild all over the country. Several varieties are found in Brazil but the two commercial types are *Zanzibar* with large seeds and low oil content and the *Sanguineus* type, with small seed and high oil content. Nearly 90 per cent of the production of Brazil is from the districts of Bahira, Sao-Paulo, Ceara, Pernambuco, Minas, Gevis and Alagoas. The beans are gathered throughout the year, although the major portion is harvested between May and October.

The production in the U.S.S.R., is estimated to have increased from an average of about 27,000 tons in 1924-28 to more than 52,000 tons during 1929-33.

The production in Argentina averaged about 3,000 tons during 1924-28 but expanded to 6,000 tons in 1934. It is reported that there are great possibilities for the expansion of this crop in this country.

According to the F.A.O. reports the world production of castor varied from 382,000 tons to 447,000 tons during 1947-55. The world production figures as received from the F.A.O., Rome, on 9-6-1956 are given in Table No. 1.

## TABLE No. 1

### World Production of Castor

| | 1947 | 1948 | 1949 | 1950 | 1951 | 1952 | 1953 | 1954 (1) | 1955 (1) |
|---|---|---|---|---|---|---|---|---|---|
| Europe (2) .. .. .. | 9·0 | 6·8 | 8·6 | 6·4 | 8·3 | 3·9 | 8·4 | 6·2 | 6·6 |
| North and Central America (3) .. | 9·1 | 5·6 | 4·4 | 5·8 | 16·7 | 18·0 | 29·3 | 12·0 | — |
| South America | | | | | | | | | |
| Brazil .. .. .. | 182·9 | 231·1 | 201·2 | 184·0 | 177·3 | 158·1 | 160·9 | 169·9 | 165·0 |
| Other South America | 16·1 | 16·4 | 15·9 | 15·3 | 13·8 | 17·0 | 20·6 | 20·5 | — |
| Total South America | 199·0 | 247·5 | 217·1 | 199·3 | 191·1 | 175·1 | 181·5 | 190·4 | 165·0 |
| Asia | | | | | | | | | |
| India .. .. .. .. | 120·0 | 110·0 | 130·0 | 103·0 | 106·0 | 108·0 | 110·0 | 126·0 | 126·0 |
| Other Asia (4) .. .. | 26·4 | 26·2 | 31·0 | 38·2 | 44·4 | 53·9 | 45·7 | 52·6 | 54·4 |
| Total Asia .. .. .. | 146·4 | 136·2 | 161·0 | 141·2 | 150·4 | 161·9 | 155·7 | 178·6 | 180·4 |
| Africa .. .. .. .. | 21·4 | 20·3 | 22·3 | 36·9 | 37·4 | 56·7 | 60·8 | 60·6 | 44·5 |
| Total World Production | 384·9 | 416·4 | 413·4 | 389·6 | 403·9 | 415·6 | 435·7 | 447·8 | 456·5 |
| Oil-equivalent of World Production | 172·3 | 187·4 | 186·0 | 175·3 | 182·6 | 187·0 | 196·1 | 201·5 | 205·4 |
| Actual Oil Production .. .. | 163·7 | 178·0 | 176·7 | 166·5 | 173·5 | 177·7 | 186·3 | 191·4 | 170·8 |
| | Thousand Metric tons | | | | | | | | |

*N.B.* (1) = Preliminary. (2) = Mostly Bulgaria and Yugoslavia. (3) = U.S.A., Mexico, Haiti. (4) = Mostly China and Thailand. — = Not available.

An extraction rate of 45 per cent has been used to convert the product weight of the crop into the oil-equivalent. The difference between the oil-equivalent of the crop and the annual quantity of oil produced is accounted for by that share of the crop which is not crushed for oil, because it goes to seed or other uses.

## Area and Production in India

The total annual area under this crop in India ranges from 1·0 to 1·8 million acres. The lowest area recorded was one million acres in 1941-42 and the highest 1·8 million acres in 1921-22. The production in most of the years averaged between 100,000 to 150,000 tons. The lowest figure was 84,000 tons in 1920-21 and the highest 151,000 tons in 1932-33.

The Marketing Department of the Government of India conducted a special survey of castor production during 1939-40 to 1941-42 and their figure for castor production in India works out to 215,000 tons of seed. Of this total production, former Hyderabad State accounted for 31 per cent, Bihar contributed 16 per cent, Uttar Pradesh 13 per cent, Bombay 13 per cent, Madras 12 per cent and Baroda 7 per cent. The balance was covered mainly by Mysore, the former Central Provinces and Orissa. The present position in regard to important castor growing States is as follows :-

### (*a*) *Andhra Pradesh*

This is by far the most important area now for castor production in India. Andhra Pradesh is estimated to have about 904,000 acres under castor and produces about 65,000 tons of seed. The crop is concentrated mainly in Mahabubnagar and Nalgonda districts.

In the Telangana part of Andhra Pradesh, castor is sown as a pure crop. Mixtures are rare. It is sown in July-August and harvested from January to March.

Castor is also largely grown in Anantapur, Kurnool, Guntur and Nellore districts. Here it is mostly raised as a pure crop but mixtures of castor with *jowar*, *Sorghum vulgare* Pers. ; *bajra*, *Pennisetum typhoides* (Burm.) Stapf ; groundnut and *ragi*, *Eleusine coracana* (Linn.)—Gaertn; are also to be found.

### (*b*) *Bihar*

The production of castor seed in this State is mainly concentrated on the banks of rivers particularly the Ganges. The average production of castor in this State is about 5,000 tons annually.

Of the total estimated production, about 40 per cent is contributed by Bhagalpur district, 14 per cent by Purnea and Monghyr, 30 per cent by the western districts of Suran, Champaran and Muzaffarpur. The balance is drawn from the districts of Darbhanga, Patna and Gaya.

In the eastern districts, a pure crop is in vogue more than mixtures. The crop is sown in September-October and harvested in March-April.

In the western districts, mixtures are more common and raised both in the *kharif* (monsoon) and *rabi* (winter) seasons. In *kharif*, castor is mixed with maize, *arhar, Cajanus cajan* (Linn.) Millsp.; or cotton and in *rabi* with mustard, peas, potatoes or chillies.

(*c*) *Bombay*

According to the Bureau of Economics & Statistics, Government of India, the area was 130,000 acres and production 18,000 tons in 1952.

Of this total production, nearly 70 per cent comes from Kathiawar and Gujarat. Castor crop is important in Junagadh, Nawanagar, Kutch, Ahmedabad, Surat, East Khandesh and Kaira.

In Junagadh, Nawanagar and Kutch, gram, *sesamum* and cotton are the common crops grown as mixtures with castor. Crops are sown in August-September and harvested in December-February.

In the other areas, castor crop is mostly raised as a pure crop. If sown as mixtures, it is mixed with cotton, *jowar, bajra* and *sesamum*. Sowings are done in June-July and harvesting in December to February.

(*d*) *Madras*

This State has an area of 36,000 acres under castor with an annual production of 6,000 tons. Salem is an important district for castor and to a smaller extent Coimbatore, Tiruchirapally and North Arcot districts as well.

About one-third of this is grown as pure, while the rest is sown as mixture with *cholam, Sorghum vulgare* Pers. ; *Cumbu, Pennisetum typhoides* (Burm.) Stapf.; groundnut, *ragi*, etc. Castor is also sown along the borders of sugarcane fields as well as a shade crop for turmeric fields and chillies.

(*e*) *Uttar Pradesh*

The State has an area of 5,000 to 7,000 acres and a production of 1,000 tons of castor seed. Of the total production, 20 per cent is drawn from northern district of Lakhimpur, 6 per cent from Sitapur and Bahraich, 30 per cent from the central districts of Etawah, Kanpur, Fathepur and Allahabad. The major portion of the balance is produced in the southern districts of Jalaun, Banda and Hamirpur.

About 95 per cent of the crop is raised as *kharif* which is sown in June-July and harvested between February and April. As a mixture, it is raised with maize, *arhar, jowar, bajra* and cotton. As a mixed crop, the yields are 200 to 300 lbs., per acre and as a pure crop 450 to 550 lbs., per acre.

(*f*) *Mysore*

The production of castor in Mysore State is about 7,000 to 8,000 tons, with an area of about 87,000 to 94,000 acres. The crop is mostly concentrated in the Chittaldrug, Tumkur, Mysore and Bangalore districts which, together, cover more than 80 per cent of the total area under castor in the State.

The crop is generally sown as a mixture with *jowar, ragi,* lablab etc. In some parts of Bangalore district, sowing is done in July and crop harvested from January to March, whereas in Mysore district sowings commence in April-May and crop is harvested in October-November.

(*g*) *Other Areas*

The total production in other areas including Assam, Bengal, Madhya Pradesh, Orissa, part of the Punjab is estimated at 10,000 tons.

In Assam, castor is mainly raised to feed the *Eri* silk worm.

The acreage and production figures for various States in India as constituted at present is given in the Table :-

**TABLE No. 2**

**Acreage and Production Figures for Various States in India**

| Sl. No. | State | Area in '000 acres. | Production in '000 tons. |
|---|---|---|---|
| 1. | Andhra Pradesh .. .. .. | 839 | 65 |
| 2. | Assam .. .. .. | 4 | 1 |
| 3. | Bihar .. .. .. | 16 | 3 |
| 4. | Bombay .. .. .. | 313 | 36 |
| 5. | Jammu and Kashmir .. .. | — | — |
| 6. | Kerala .. .. .. | — | — |
| 7. | Madhya Pradesh .. .. .. | 22 | 4 |
| 8. | Madras .. .. .. | 34 | 6 |
| 9. | Mysore .. .. .. | 113 | 8 |
| 10. | Orissa .. .. .. | 52 | 4 |
| 11. | Punjab .. .. .. | — | — |
| 12. | Rajstahan .. .. .. | 4 | 1 |
| 13. | Uttar Pradesh .. .. .. | 6 | 1 |
| 14. | West Bengal .. .. .. | — | — |
| 15. | Delhi .. .. .. | — | — |
| 16. | Himachal Pradesh .. .. .. | — | — |
| 17. | Tripura .. .. .. | — | — |
| | Total .. .. | 1403 | 129 |

*Final Estimates for 1956-57.*
*(Indian Oilseeds Journal 1957, 1:5)*

## CHAPTER III

# BOTANICAL CLASSIFICATION

Family :—*Euphorbiaceae*

Genus :—*Ricinus*

Species :—*communis*

*Ricinus communis* Linn. Fl. Br. Ind. V. 457.

The name *Ricinus* is a latin term meaning 'Dog tick', and was given to this plant by Linnaeus because of the resemblance of the seed to that canine pest. Linnaeus grouped all the varieties of the plant under one species *Ricinus communis* Linn. Watt[152] maintains the same view and says that under this single species there are numerous varieties and some writers designate these varieties as subspecies although they would seem to possess no higher claim than that of cultivated races. Some workers have tried to divide the Linnaean type into varieties according to the size of the seed and some on the basis of the characteristics of the inflorescence. But these classifications do not satisfy the botanists, as these are purely morphological. G. M. Popova,[104] a Russian worker, has tried to divide the species *communis* into the following subspecies :-

| | | | |
|---|---|---|---|
| Persian variety | — | Subspecies | *Persicus* G. Popova |
| Chinese variety | — | ,, | *Chinensis* G. Popova |
| Zanzibar variety | — | ,, | *Zanzibarinus* G. Popova |
| Blood red | — | ,, | *Sanguineus* G. Popova |
| African | — | ,, | *Africanus* G. Popova |
| Mexican | — | ,, | *Mexicanus* G. Popova |

This classification is based on eco-geographical grouping. But the last three resemble each other so closely that it makes their identification very difficult. Hence Hilderbrandt[53] suggests that the last three be placed under one group namely "Indo-African." He gives the following description of these subspecies :-

(1) The Persian Variety (Subspecies *Persicus* G. Popova)

This group is found in Iran, India, Middle Asia, Transcaucasus, North Caucasus, and the Ukraine.

It has two outstanding morphological characters. The inflorescence is elongated, narrow, conical, and the fruits may cover the flower stalk to the base. Its seed is oval, small, and has no caruncle when ripe.

It is one of the most productive of the known forms. It is medium as regards time of maturity. There are no extreme late forms in this type. Most of the varieties in this type are shattering and this necessitates early harvesting and drying of the capsules.

This subspecies is comparatively homogeneous. Depending on morphological characters, this subspecies can be subdivided into four types :

*Type 1* :—In north Caucasia, this type ripens in 85 to 100 days. Inflorescence dense, narrow, elongated. capsules spiny. Fruits are shattering. If sown thickly, this type does not produce branches. The main spike produces a large number of fruits and hence can stand close planting. This is the most productive of all the types.

*Type 2* :—Medium as regards time of maturity ; duration is 96 to 126 days. Plant develops vigorously with thick stems and large leaves. Inflorescence is dense. The plants are with or without bloom. The side branches are larger than in type 1.

*Type 3* :—An early type taking 80 to 100 days for ripening of side inflorescences. Inflorescence loose. Fruits are spiny and spines are smaller than in the preceding two types. A peculiar characteristic of this type is its profuse branching. The plants are with or without bloom.

*Type 4* :—Medium as regards time of maturity, duration being 95 to 130 days. Loose inflorescence. This type differs from the preceding, in that, the inflorescence bears in its lower and sometimes in the middle part a few elongated fruit-stalks, each bearing a few fruits. Number of branching is only one to two. Plants of this type are tall, growing to a height of 120 to 200 cm.

(2) The Chinese Subspecies

The forms of this subspecies are found in west China and Manchuria. This subspecies is early, being 75 to 97 days in duration. The inflorescence is short and loose with a broad, conical shape. Seed is oval and large and grey coloured with a small caruncle. Plants are very branchy upto 13 branches.

This subspecies is less productive and the seed is distributed over a large number of small inflorescences. This cannot be planted close. The main

features of this subspecies are its earliness and non-shattering character of the capsules.

The sub-types of this subspecies are as follows :—

*Type 1* :—*The Western Chinese Type.* Plants have bloom and the capsules are spiny and non-shattering. Maturity period is 80 to 97 days and plants are 90 to 150 cm., in height. It is the most productive type in this subspecies.

*Type 2* :—*The Manchurian Type.* Similar to type 1: but the green colour of the stem is mixed with anthocyanin purple colouring.

*Type 3* :—*The Ukrainian Type.* This is very early, requiring only 77 to 85 days for maturity. The stem is slightly purplish in colour. The main features of this type are, capsules non-shattering, the valves of the capsules (or the husk) are so thin that they get powdered on threshing and are thus very easy to thresh. This type is found as admixture in the south of the European part of the Soviet Union.

(3) The Indo-African Subspecies

In this subspecies, Hilterbrandt[63] has grouped all forms described by Popova under the names of the blood-red, the African and the Mexican subspecies, on the basis of a common origin for these forms and the frequent coincidence of their areas, etc.

This subspecies is spread over a wide area and is to be found in four continents. Because of this, the ecological diversity of this subspecies is very great. Many features belonging to castor are found in extreme degrees in this subspecies. The diversity in morphological characters is greater than in any subspecies. This subspecies possesses 88 per cent of all the known characters of castor plant and as a consequence is very valuable for breeding purposes.

The outstanding characteristics of this subspecies are :—Seed elongated, narrow at the caruncle which is well-developed. The shape of inflorescence varies. The lower part of the flower stalk is usually free of pistillate flowers. Many anthocyanin forms are found.

This subspecies could be divided into a number of sub-types ; but the most important ones are the following :-

*Type 1.* (*The wild type*) :—Wild forms are found in Africa, but they should not be confused with certain forms that have reverted to the wild form, and

are found elsewhere. This form is of medium height, with thin stem and branches and small leaves. The stem is green and mixed with anthocyanin colour, no bloom ; the inflorescence is short, very loose, with very few fruits covered with spines ; capsules shattering, small-seeded.

*Type 2.* (*Late, large-sized*) :—This type is found in tropical countries, in Abyssinia, Eritriea, Mexico, Guatemala, Peru and India. Earlier-maturing types are found in some regions as in north India and south Afghanisthan.

The inflorescence is medium-sized, broad at the base and fixed on a long stalk. The stem is thick, leaves large. Stem green or red. With or without bloom. The seeds vary in colour and size.

*Type 3.* (*Large-sized*) :—Time of maturity medium. The forms of inflorescence vary. Size of capsules and seed vary. This type has non-shattering forms also. This type is spread in Afghanisthan, Tadjikisthan, Iran and eastern Mediterranean.

*Type 4* (*Medium-sized*) :—Time of maturity medium. Capsules both shattering and non-shattering. Plants with or without bloom.

The above types form a continuous chain of intermediate forms beginning with late-maturing African forms and ending with Asiatic forms with medium maturity.

Besides the above four types Hilterbrandt describes three more types under this subspecies. These are *Type 5*—small-sized type, *Type 6*—with dense inflorescence, *Type 7*—with broad inflorescence and early maturing. But the difference in these types is only morphological.

(4) Zanzibar Subspecies (*Zanzibarinus* G. Popova)

This subspecies is found in the tropical parts of Africa and America and in Europe as an ornamental plant. Most forms of this subspecies are late-maturing.

The subspecies has almost square-shaped seeds, with well developed caruncle. The inflorescence is cylindrical or ellipsoid in shape. The capsules are large and spherical. The plants are strongly developed with thick branches, and large-sized leaves.

The above grouping is based mostly on morphological characters and hence may be considered artificial.

Though there exists a remarkable multiplicity of forms in castor, yet they all cross with each other freely and all the forms pass into one another by numerous transitions and thus prove that they constitute a single group, which is hardly more than cultivated states of one species, namely, *Ricinus communis*.

Castor is very responsive to environmental differences. Characters such as height of plant, height at which main spike appears, the length and compactness of spike, branching habit, are all greatly affected by environments. Plants, when occurring in rows hardly produce two to three side spikes, produce as many as 30 side spikes when occurring as isolated plant on rich soil. Hence any classification based on such characters will be artificial and will only be applicable to a particular set of conditions. Such a classification does not comply with the requirements of botanical classification. At Hyderabad, samples of castor seed were obtained from countries such as Brazil, U.S.A., Egypt, British Somaliland, Russia and Persia. Though the plants from these samples differed greatly from Indian castor in growth habit, yet, they all easily crossed with Indian castor. Though castor possesses a large number of contrasting heritable characters, yet, these are not helpful in separating the forms into different species. Hence it is felt that the genus *Ricinus* has a single cultivated species, namely, *communis*. In India practically every form of castor that has been described by Popova and Hilterbrandt could be found except, the very early-maturing types like *chinensis*, maturing in about 75 to 90 days and the Zanzibar types.

CHAPTER IV

# BOTANICAL DESCRIPTION

The botanical description of the monotypic genus, *Ricinus*, is given by J. D. Hooker[65] as follows :-

A tall, glabrous annual, sometimes shrubby or sub-arboreous, leaves alternate, broad, palmately 7 to many-lobed, serrate ; flowers large, in terminal sub-panicled racemes, monoecious, apetalous, upper male crowded, lower female ; Disk O.

*Male flowers* :—Calyx membranous, splitting into 3-5 valvate segments ; stamens very many, filaments crowded, variously connate or in branching clusters, anther cells distinct, distant, subglobose, divergent. Pistillode O.

*Female flowers* :—Calyx spathaceous, caducous ; ovary 3-celled ; styles short or long, spreading, often very large, entire 2-fid or 3-partite, feathery or papillose ; cells 1-ovuled. Capsule of 3, 2-valved cocci. Seeds oblong, testa crustaceous, albumen fleshy ; cotyledons broad, flat.

Under *Ricinus communis* the description given by the same author is as follows :-

Cultivated throughout India and naturalised near habitations. Distribution : tropics generally, probably indigenous to Africa.

An evergreen bush or small tree. Shoots and panicles glaucous. Leaves green or reddish, 1-2 feet diameter, membranous, lobes from oblong to linear, acute or acuminate, gland serrated ; petiole 4-12 inches Racemes stout, erect. Male flower $\frac{1}{2}$ inch in diameter ; female calyx nearly as long ; styles often highly coloured ; capsule $\frac{1}{2}$-1 inch long, globosely oblong, smooth or echinate. Seeds oblong, smooth and mottled.

## 1) Plant Habitat

The plant, if grown on a field scale, is an annual requiring about 280 days from seeding to drying. But if it is grown in gardens or in back-yards of houses where there is a constant supply of water, the plant lives for a number of years. Both the annual and perennial are branchy types. This branchy character is very much influenced by environmental factors such as type of soil, fertility of soil, moisture, spacing, etc. Each branch bears one or more spikes and

hence, as a field crop branching is preferred. Annual plants may have from 3 to 30 side spikes depending on environmental conditions. In the case of perennials the plant may attain heights of 30 feet even, and naturally, will have very large number of branches and spikes.

Attempts have been made to breed types with a single main spike, *i.e.*, plants with no branches. Under dry conditions, lines were obtained with no branches and the plants bearing a single main spike. But the same lines under favourable moisture conditions put forth branches.

Types having primary branches, secondary and tertiary branches have been obtained. The main spike is the first to emerge ; 20 to 30 days later primary branches emerge and at the same intervals secondary and tertiary. This prolongs the harvesting period from December to March. It will therefore be most advantageous if strains bearing single spikes but yielding as much as those with three orders of branching could be isolated. This will simplify the harvesting and the crop will be off the field within 6 months, whereas now it takes 9 to 10 months.

In Hyderabad high yielding non-branching strains have been developed. Under Madras conditions these strains are not promising because optimum weather conditions are not generally available at the time of flowering. The Madras strains which are branching types are able to give higher yields because they are able to get over adverse seasonal conditions. In the U.S.A., dwarfish, highly branched types have been isolated and the spikes in these have uniform maturity and are suitable for machine harvest.

### 2) Height of Plants

Like branching, the plant height is also greatly influenced by environment. It is usually found that in poorer types of soils and scarcity of moisture, the plants attain heights of one to three feet but the same varieties, if planted in fertile soils with good rainfall conditions, may attain heights of 10 to 14 feet. Types have also been isolated which are comparatively dwarf even under favourable conditions. These types usually attain heights of only two to three feet.

As a field crop it is not advantageous to have plants taller than five to six feet. If they are taller, harvesting becomes very difficult and damage due to heavy winds is also severe.

The tall growth of castor is sometimes utilised to advantage by planting it along the borders of fields to serve as a wind-break and also gaining some income in the form of seed yield.

### 3) Colour of Stem

Castor plant shows a number of stem colours. The ones that have been observed and maintained at Himayatsagar in pure condition are :—

Blood-red colour is to be found in plants having no bloom whatsoever.

Red and green are the normal colours to be found in castor. Practically all cultivated varieties in India belong to either red or green types.

Pink and sulphur-white stems are to be found mainly in ornamental varieties grown in gardens, although these plants thrive well in the fields also.

Mahogany-coloured stems are also met with.

White (1918) classified the stem colours into five categories, *viz.*, (1) bright green, (2) green with reddish blush on the sunny side, (3) carmine or rose-red, (4) mahogany red and (5) purple (dark-red). In Madras Seshadri and Varisai Muhammad (1951) have reported four distinct stem colours, *viz.*, mahogany, red, red-blush and green. In the absence of a unified code, different workers have recognised different grades of stem colour.

### 4) Leaves

The size of leaf varies in different varieties. Certain varieties are characterised by large leaves while others bear only small leaves.

The leaves are simple and palmate. The number of lobes vary from 7 to 11. There are very few leaves either with 7 or 11 lobes and the great majority have 9 or 10 lobes. The length of leaf (measured as from base of leaf to tip of mid lobe) varies a great deal. The maximum length is about 13 inches. The lacination is not deep but it may be very close or wide apart.

The leaf is usually green, but this is associated with the colour of the stem. In case of green stem, the leaf and mid ribs are all green. In case of red stem, the young leaves have a red tinge which disappears after the leaf is fully developed when it becomes green ; but the mid rib maintains the reddish tinge.

### 5) Blooms on the Plant

Bloom or the waxy coating found on the stem and certain other parts of the castor plant is a natural protection to the plant both from extremes of weather and from some insect pests.

Castor raised in the *rabi* season (October to May) showed that plants without bloom suffered more from cold than plants with bloom and also showed that the former suffered a more severe attack of Jassids than the latter. The colour of the bloom is ashy white. The types of blooms found on castor have been described under the following categories :

No bloom : With no bloom or waxy material whatsoever on any part of the plant.

Single-bloom : With bloom only on stems, but not on leaves or fruits.

Double-bloom : With bloom on stem, fruits, and on the lower (dorsal) side of leaf, but not on the upper surface (ventral) of leaf.

Triple-bloom : With bloom on every part of plant such as the stem, petiole, upper and lower surfaces of leaves and on fruits.

Narain Anubhava (1952) has described different grades of bloom on castor.

Most of the cultivated varieties of castor in India come under the double and triple-bloom groups.

### 6) Inflorescence

Usually the main axis and the branches terminate in inflorescences. Dharampal Singh[30] reports of a case where four inflorescences appeared and developed simultaneously, but such cases are very rare. Under adverse soil and rainfall conditions, inflorescences often emerge when plants are hardly 8 to 12 inches tall, while the same variety under optimum soil and weather conditions, gives out the main spike at a height of 75 to 90 inches.

The inflorescence first appears in the form of a bud. The time required for the appearance of such a bud from seeding, varies with different varieties. Masur[90] gives a range from 35 to 105 days. Dharampal Singh[30] found a range of 28 to 165 days at Kanpur. At Himayatsagar Farm this range was from 30 to 180 days.

For the bud to develop into a raceme it takes 8 to 15 days. Dharampal Singh[30] found that at Kanpur it took 15 days, while at Himayatsagar it took 10 days.

When all the flowers on a spike have fully emerged, it is easy to make out as to whether the spike is mostly female, partially female or otherwise. (The types are described under item 8 below).

7) Sequence of Opening of Flowers

It is commonly believed that the staminate flowers open first. Joshi[70] in a study of 457 individuals belonging to different varieties found that in 61 cases the staminate flowers opened first and in 67 cases the pistillate flowers opened first, whereas in a large majority of cases both types opened almost simultaneously. The interval between opening of the two types of flowers varies a great deal. In extreme cases one type may never appear while the other may keep on opening.

In the studies conducted at Himayatsagar Farm, the following observations have been made :

*a*) Pistillate flowers commence opening at 11 p.m. but the maximum numbers open between 4-30 a. m. to 5 a.m., at a temperature of 71°F.

*b*) The staminate flowers commence opening at 5 a. m. when the temperature was 71°F.

*c*) By following the aestivation of the bud, the female flower was artificially opened and pollination was effected with the help of camel hair brush. The stigma was found to be mature and receptive even 12 hours before opening time. Similar experiments showed that the stigma continues to be receptive for 72 hours after opening of the flower.

*d*) Pollen was collected from freshly-opened staminate flowers and was used for pollinating fresh stigmas at six-hourly intervals. It was found that the pollen so collected remains viable and is capable of fertilisation for 60 to 66 hours from the time of opening of staminate flowers.

Seshadri and Varisai Muhammad (1951) have reported that female flowers are found to exert the stigmatic lobes practically throughout the day and that it takes nearly one to three days for them to attain full development and become receptive.

Meinders and Jones[93] observed that pollen was shed from 4 a. m. to 8 p. m. However, heavy shedding took place between 7-30 a. m. to 11-30 a. m. Pollen shedding began at a temperature of 75°F and relative humidity of 70 per cent. It reached its peak between 80° to 86°F and at a humidity of 60 per cent. A temperature of 60° F appears to delay shedding.

The staminate flowers were found to shed pollen for an average of 15.67 ±0.34 days in August and 16.32±0.39 days in June. A correlation coefficient of —0.18 was found between the number of staminate flowers and the length of time required for the raceme to complete pollen shedding, indicating that lines with different numbers of flowers per spike could be developed to shed pollen over a long or short period. Such lines might prove of value in the production of hybrid castor (Dharampal Singh.[30])

8) Nature of Spike

In castor, both the pistillate and staminate flowers are borne on the same peduncle and thus it forms a monoecious raceme. Usually the pistillate flowers are at the top and the staminate ones at the base. However, a number of cases were noted by Joshi,[70] Classen and Hoffman,[20] where both the lower and upper parts had both types of flowers. About 10 cases were observed where the topmost flower of the inflorescence was male; and many cases were also found in which the very first and the lower-most flower was female. In the observations made at Himayatsagar it was found that in certain cases, the male flowers were interspersed between the female flowers up to the tip of the spike.

In a normal inflorescence, the pistillate flowers occupy about 30 to 50 per cent of the portion of spike and the remaining lower portion by staminate flowers. Joshi[70] has observed racemes with 100 per cent pistillate flowers. At Himayatsagar Farm, by 1936, varieties with spike types of 95 per cent pistillate flowers were evolved. Classen and Hoffman[20] made the same observations later (1950). Joshi[70] also found one spike with all male flowers. Cases of few hermaphrodite flowers were also observed by Joshi,[70] Classen and Hoffman[20] and also by Seshadri and Varisai Muhammad (1951) at Tindivanam in Madras State. At Himayatsagar Farm, parthenocarpy was observed. In the castor work at Kanpur, Dharampal Singh[30] observed racemes with 90 to 100 per cent female flowers with the male and female flowers interspersed in the inflorescence.

Narain Anubhava[95] reported a mutant which showed a single flower mutated at the top of the inflorescence, while the rest of the flowers retained their normal position. The proportion of the part of raceme occupied by each type of flower gives a different appearance to the spike and these form different types. These types could be classified into three major groups as follows :—

a) *Mostly female spike* :—Pistillate flowers appear from the base of the spike covering the entire length with fruits. The staminate flowers are clus

tered at the very base of the peduncle and sometimes dispersed in female flowers at the lower end only.

At Himayatsagar Farm this character has been maintained in pure form. In mostly female plants, it is not only that the main spike alone is mostly female but even side spikes, upto the fourth order, are also mostly female. This character is greatly stressed in castor breeding at Himayatsagar and hence practically all improved material is of this type.

b) *Partially female spike* :—Roughly the upper half of the spike length is full of pistillate flowers, (and hence full of fruits) while the lower half bears staminate flowers and hence gives a vacant appearance.

A number of improved strains of castor isolated by various breeding stations in India belong to this group.

c) *Mostly male spike* :—Fruits clustered only at the upper one-third of the spike. The remaining lower two-thirds is occupied by male flowers, which wither and thus give an empty look.

The local varieties of castor of Telangana part of Andhra Pradesh and also of many other States are of this type.

These last two groups also could be maintained pure with a certain amount of latitude for the proportion of female to male flowers.

Records of the proportion of female flowers to male flowers in particular inbred lines of castor show appreciable variations from year to year. Shifriss[130] has reported that in castor gene $F_1$ for monecesum controls a genetically stable series of sex variants ranging from female 'f' to strong male inbreds and the sex expression of these strains is subject to non-genetic variations which occur intermittently during the development of individual plants.

### 9) Shape of Spike

Great morphological variations are to be found in this character. The different shapes are mostly confined to the mostly female group described above. In case of mostly male group, there are no different shapes while in case of partially female group, certain shapes are discernible but are not so conspicuous. The following are the more important shapes found in mostly female types:—

a) *Long cylindrical* :—Though the tip of the spike usually becomes narrow, yet, the whole appearance is like a narrow cylinder with uniform diameter.

*b) Long conical* :—At the base, the spike is broad and becomes very narrow at the tip, thus giving an appearance of a cone.

10) Compactness of Spike

This character is clearly discernible in mostly female spikes. In case of partially female and mostly male types, the spikes are usually loose to 'very loose'. The length of the spike on which fruits are borne and the number of fruits gives a measure of compactness. This can be expressed in terms of fruits per linear length. Masur[90] reported a case where the number of fruits borne over 33 cm. length were 197, *i.e.*, 6 fruits per cm.

Studies on the fruit development on the rachis of castor were conducted at Himayatsagar during 1940 to 1944. Material studied was two improved strains namely H.C-1 and H.C-2 and local castor. The data revealed that H.C-1 has a spike with an average length of 12 to 13 inches ; H.C-2, 16 to 20 inches ; and local, 20 to 23 inches. In the case of H.C-1 and H.C-2, the first 5 inches of the main spike from the base of peduncle carry 70 per cent of the total number of fruits, the second 5 inches 28 per cent and the remaining length only 2 per cent. This gives a compact appearance to the spike. In case of local, the first six to eight inches from bottom are without fruits, the next five inches carry 25 per cent of the total number of fruits, the third five inches another 30 per cent and the remaining length 45 per cent. Table No. 3 gives the actual data obtained.

TABLE No. 3

**Percentage of the Total Fruits Borne per Linear Length of the Spike for Strains H.C-1, H.C-2 and Local Castor.**

| Linear length from base of peduncle | | H.C-1 | H.C-2 | Local |
|---|---|---|---|---|
| 1st | inch .. .. .. .. | 9·94 | 8·22 | 0 |
| 2nd | ,, .. .. .. .. | 15·36 | 12·78 | 0 |
| 3rd | ,, .. .. .. .. | 17·64 | 17·46 | 0 |
| 4th | ,, .. .. .. .. | 16·31 | 16·01 | 0·50 |
| 5th | ,, .. .. .. .. | 12·15 | 13·21 | 2·15 |
| 6th | ,, .. .. .. .. | 9·32 | 9·80 | 4·54 |
| 7th | ,, .. .. .. .. | 7·84 | 7·32 | 8·57 |
| 8th | ,, .. .. .. .. | 5·08 | 5·66 | 12·81 |
| 9th | ,, .. .. .. .. | 3·09 | 3·79 | 12·06 |
| 10th | ,, .. .. .. .. | 2·85 | 2·67 | 14·48 |
| 11th | ,, .. .. .. .. | 2·99 | 2·55 | 12·25 |
| 12th | ,, .. .. .. .. | 0·09 | 1·60 | 10·04 |
| 13th | ,, .. .. .. .. | 0·03 | — | 7·71 |
| 14th | ,, .. .. .. .. | 0·01 | — | 6·10 |
| 15th | ,, .. .. .. .. | 0·01 | — | 3·43 |
| 16th | ,, .. .. .. .. | — | — | 2·57 |
| 17th | ,, .. .. .. .. | — | — | 1·21 |
| 18th | ,, .. .. .. .. | — | — | 0·90 |
| 19th | ,, .. .. .. .. | — | — | 0·55 |
| 20th | ,, .. .. .. .. | — | — | 0·50 |
| 21st | ,, .. .. .. .. | — | — | 0·10 |

*The percentages given above are averages of 100 plants in each case.*

The following are the main types noticed :—

a) *Firmly compact* :—Fruits are set very close and no space is left between fruits. The fruits cannot move. This type harbours insect pests and is not suitable for field crops.

b) *Compact* :—Fruits are set close to each other but slight space is left in between fruits.

c) *Loose* :—Fruits are set well apart from one another.

*d*) *Very loose* :—Fruits are very much further apart.

11) Nature of Fruits

a) Spiny

b) Non-spiny

In case of spiny fruits there is variation in the length of spines. In some cases the spines are short and in some long. There are about 150 spines per fruit. In case of non-spiny fruits, the skin of the fruit is generally smooth. The non-spiny fruits can be further sub-divided into two groups, (i) smooth and (ii) warty where the epicarp is rugged.

12) Size of Fruits

There is great variation in the size of fruits. In general, the size of seed is in direct proportion to the size of fruits. The size of fruits could be divided into four major groups, namely, a) *Very small*, b) *Small*, c) *Medium* and, d) *Large*.

The large fruits usually contain large seeds which have a low oil content, *i.e.*, less than 40 per cent on the whole seed. In Madras, a large-seeded perennial variety has the highest oil content. The medium and small seeds are the two groups to which most of the cultivated varieties of Indian castor belong. Their oil content varies from 45 per cent to 57 per cent. Very small fruits are usually found in ornamental plants in some perennial types and some times as a variation in cultivated varieties.

13) Colour of Fruits

Practically, all cultivated varieties have green fruits. But plants with grades of mahogany, pink and sulphur-white fruits have also been observed and isolated.

14) Locules in Fruits

There are usually three locules in castor fruit. But fruits with two and four locules have also been noticed and Bhavanishanker Rao and Thandavarayan[7] have reported the occurrence of 4 to 8-loculed capsules and also fruits having two ovules in each carpel.

15) Fruit Dehiscence

The local varieties raised by the farmers are all dehiscent and hence harvesting of fruits has to be done before the fruits are completely dry. The harvested fruits are then dried in the sun and threshed. Dehiscent fruits are very easy for threshing, but harvesting them before full maturity affects the oil content. This subject will be dealt with at a further stage.

The improved strains evolved at Himayatsagar and Madras are all non-dehiscent. Thus, the farmer can afford to wait till all the fruits on a spike are dry and then harvest them without fear of losing seed by dehiscence of fruits. Such fruits are, no doubt, slightly harder to thresh.

There are also types that are partially dehiscent. In this case, the locules open but the membranes that cover the seed remain intact and hence the seed does not fall off.

16) Seed Size

There is a great range of variation in seed size. The smallest seed noticed is 7.95 mm. $\times$5.30 mm., while the largest is 20.95 mm. $\times$13.50 mm. Between these two extremes all intermediate stages could be found. The common cultivated types have seed-size ranging from 11.19 mm. $\times$7.79 mm. to 13.54 mm. $\times$9.80 mm. The number of seeds per pound may vary from 4550 to 5000 in small sized types to 450 in big sized types.

17) Caruncle

In the Indian varieties, caruncle is always present. So far no varieties have been noticed, without caruncle, like the Persian variety described by Popova. But it is not known how the caruncle helps the seed because even if it is removed the seed germinates as usual.

18) Seed Colour

A number of colours are to be found in castor seed. The most striking ones are:—Red, white, grey, faint chocolate, deep chocolate and purple.

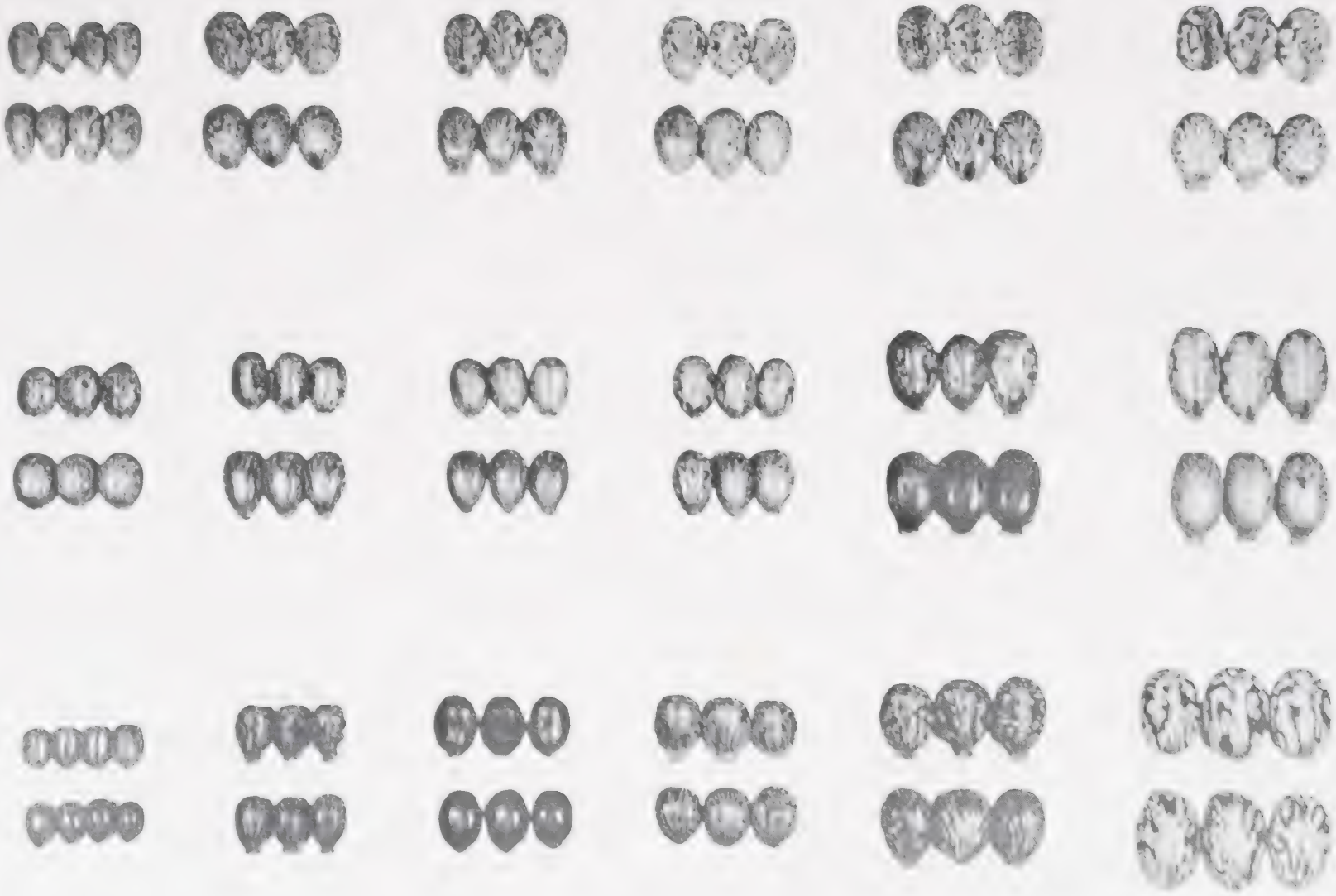

*Plate I — Showing variation in seed size.*

The ground colour of the seed is modified by the overlay pattern and colours of mottling and these are reported to be independently inherited.

19) Mottling on Seed

A great variation is to be found in the expression of this character. The range is from no mottling to such thick mottling, that at times it is difficult to distinguish between the ground colour and the colour of mottling.

20) Space Filled by Endosperm within the Seed Coat

In most cases, the endosperm completely fills the space within the seed coat. This makes the seed heavy and difficult to be crushed easily by pressing with fingers. But there are medium-seeded varieties where the endosperm does not fully fill the space within the seed coat. Some empty space is left. Such seed is easy to crush by pressing with the thumb. This should not be confused with shrunken endosperm resulting from want of moisture in the field at the time of seed formation. This character of the endosperm not filling the seed cavity completely, causes some damage to seed at the time of threshing. With seed that is well filled, there would be hardly any broken seed after threshing, but with seed that is not well filled with endosperm, there would be usually five per cent broken seed at the end of threshing. In Madras poor filling is generally associated with large-seeded types and this character is responsible for the low oil content of these types.

21) The Root System

The root system consists of main tap root, secondary roots and tertiary roots. The tap root looks like an extension of the stem below the soil. In the studies at Himayatsagar, it was observed that the tap root, in extremely poor soils, goes down to 16 feet while descending downwards; if it meets any hard material, the tap root would take a turn to avoid it and then again goes down. The secondary roots are branches of the tap root and these are restricted to the upper 30-inch region. The secondary roots mostly travel parallel to the ground, with a slight bend downwards. These grow to about three or four feet. The tertiary roots are not very long, hardly 12 to 18 inches. Root hairs have not been noticed in castor.

In Madras State root studies were carried out on three varieties of castor, representing the short, medium and long-duration types. A distinct relationship between duration and root development was noticeable. High rate of development is seen during the early period in the short-duration types while it is later in the other two types. The long-duration type showed longer

lateral roots with greater penetration, as compared with short and medium-duration types.

It was also observed in laboratory studies that the seed coat breaks longitudinally after 80 hours and the radicle emerges at the same period. The secondary rootlets commence after 120 hours. Within eight days, the radicle reaches a maximum length of 23.5 cm. and the number of rootlets to even 70. Observations were recorded on seven strains and local, and it was found that the above characters vary greatly with each strain.

CHAPTER V

# OIL DEVELOPMENT IN CASTOR

Castor is an important commercial crop which is industrially valued for the oil which its seeds contain. It is therefore not only interesting but also necessary to trace its development in the castor bean and to determine and understand the factors influencing it. Much work does not seem to have been done along these lines either in India or in foreign countries. Sethi [127] studying the problem in Uttar Pradesh, concludes that earlier formed beans contain more oil than the later ones, and that seeds borne on the main fruiting spike are richer in oil content than those on the secondary or tertiary branches.

At Himayatsagar Farm, Hyderabad (Dn.), studies on different aspects of oil formation were carried out over a number of years. The results of these studies are summarised below :—

## 1) Determination of Oil in Seed from Capsule Discernibility to Capsule Maturity

This study comprised a time-series. The questions attempted to be answered were :—

*a*) At what time in the development of capsules is oil formed so as to be analytically traceable ?

*b*) What is the rate of increase ?

*c*) When is the maximum quantity reached ?

*d*) Is there any falling off thereafter, if mature capsules ready for picking are left unpicked ?

These observations were made on two improved strains, namely, H.C-1 and H.C-2 with the local variety also, in the second year. Twenty plants were taken at random in each case at the same period of flowering bloom. Ten days after flowering, capsules were discernible and regular pickings were started at eight to ten days interval. Twelve such harvests were taken from each spike. At each harvest four equal-sized fruits from the main spike of each of the 20 plants were picked and analysed for oil. Fifty to sixty days after flowering, all the main spikes were dry but the harvests were continued periodically for another 70 days in order to see if any falling off in oil content

occurred, if capsules were left on the plants after maturity. The oil analysis figures have been averaged for the 20 plants and shown in Table No. 4. The figures given are actual oil percentages on whole seed determined by ether extraction.

It will be seen from the Table that, in general, the oil content increases from the first to the last harvest except one in the case of H.C-1, and last but two pickings in H.C-2 and local. This clearly shows that varieties do differ in this particular character. Further, in all the three cases, a common feature is seen, namely, a falling off after the maximum has been reached. This decrease has been least in H.C-1, a little more in H.C 2 and the maximum in the local type. One of the most important points to be noted is that the oil content goes on increasing even after the dry stage is reached, *i.e.*, even after the fruits on the spike have dried. This increase in oil content continues for over 30 days after the dry stage. Thus the correct time of harvest would be not immediately after the fruits are dry but atleast 20 to 30 days after the fruits are dry. To achieve this, it is essential to have fruits of a non-dehiscent nature.

In the rate of increase in oil content, it will be noticed that the rates vary from year to year, indicating thereby that seasons have considerable effect on the rate of depositing of oil. In the first 30 days after fruit discernibility, only a very small quantity of oil is deposited. In the next 10 to 20 days, a very rapid increase takes place and nearly two-fifths of the oil is deposited. In another 10 days, *i.e.*, from 50th to 60th day after fruit discernibility, the rate is nearly doubled. Roughly, between 50th and 60th day after fruit discernibility, nearly 80 per cent of the total oil is deposited. After 60 days, the rate rapidly falls down. It will also be seen from the above Table that the period during which maximum oil is deposited varies from season to season. These studies also serve to indicate the period when castor plants require the maximum nutrition.

Studies on oil formation carried out at Coimbatore (Madras) have shown that in the first three weeks after capsule discernibility 30 per cent oil was deposited and this rose to 48 per cent by the sixth week. Thereafter the oil depositing was very slow.

(2) Studies in the Oil Content of Seed in Capsules Formed from the Various Flowering Periods (Early, Mid and Late) on the Same And Different Spikes.

In castor, all the female flowers on a spike do not open at the same time A spike with 60-70 female flowers takes about 10 to 12 days for full opening. This period was divided into three parts. Those flowers which opened within

## TABLE No. 4.

**Comparative Oil Development in H.C-1, H.C-2 and Local Based on Average of 20 Plants at Successive Harvests**

FIRST YEAR

| Strain | .. | .. | Sept. 10 | Sept. 20 | Oct. 1 | Oct. 10 | Oct. 20 | Nov. 1 | Nov. 20 | Dec. 1 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | ——Dry stage—— | | |
| H.C.-1 | .. | .. | 1·57 | 16·26 | 30·62 | 39·09 | 41·85 | 44·50 | 45·84 | 49·46 |

| | | | Sept. 29 | Oct. 9 | Oct. 19 | Oct. 29 | Nov. 9 | Nov. 19 | Nov. 30 | Dec. 10 | Dec. 21 | Dec. 31 | Jan. 10 | Jan. 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | ——Dry Stage—— | | | | | | | |
| H.C.-2 | .. | .. | 1·92 | 4·05 | 17·84 | 21·04 | 40·81 | 46·00 | 46·74 | 48·43 | 49·10 | 50·59 | 48·75 | 53·52 |

SECOND YEAR

| | | | Sept. 14 | Sept. 20 | Oct. 2 | Oct. 11 | Oct. 28 | Nov. 11 | Nov. 20 | | Dec. 1 | Dec. 10 | Dec. 20 | Dry stage Nov. 1 onwards. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H.C.-1 | .. | .. | 4·26 | 1·53 | 1·03 | 2·28 | 21·10 | 43·75 | 47·22 | | 48·18 | 49·25 | 49·03 | |

| | | | Sept. 16 | Sept. 24 | Oct. 4 | Oct. 14 | Oct. 26 | Nov. 3 | Nov. 13 | Nov. 23 | Dec. 3 | Dec. 13 | Dec. 28 | Jan. 4 | Jan. 13 | Jan. 21 | Jan. 31 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Dry Stage Nov. 10 onwards. | | | | | | |
| H.C.-2 | .. | .. | 1·82 | 1·41 | 5·92 | 20·20 | 44·10 | 44·38 | 46·50 | 46·82 | 48·84 | 49·62 | 49·04 | 48·48 | 49·09 | 50·30 | 49·55 |

| | | | | | Oct. 5 | Oct. 15 | Oct. 27 | Nov. 6 | Nov. 23 | | Dec. 9 | Dec. 17 | Dec. 27 | Dry stage Nov. 10 onwards. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Local | .. | .. | | | 3·64 | 32·23 | 19·87 | 22·13 | 30·37 | | 48·12 | 45·88 | 47·93 | |

first 3-4 days were designated as early, those that opened after 3-4 days but before 7-8 days were termed as mid-bloom flowers, and those that opened after 7-8 days as late bloom. All this was on the same spike. Studies on ten such spikes were conducted. Fruits from each flowering bloom and from each spike were harvested separately and analysed for oil. In each case, 10 determinations of oil were made. Studies were conducted on strain H. C-1. The data are as follows :—

| | |
|---|---|
| Difference between early and mid-bloom on the same spike | $0.59 \pm 1.18$ |
| Difference between early and late-bloom on the same spike | $0.41 \pm 1.33$ |
| Difference between mid and late-bloom on the same spike | $0.11 \pm 1.38$ |

The differences were not statistically significant.

The same problem was studied from the viewpoint of the crop. The question sought to be answered was whether any significant variation exists in the oil content of plants whose flowering period is early, intermediate and late.

In all, 30 plants selected at random were studied. Of these, 10 belonged to each of the 3 flowering periods namely early, mid and late. The difference between each bloom of flowering was about 30 days. The fruits of the 10 plants in each of the 3 sets were picked after drying, and analysed separately. Table No. 5 gives the oil data.

TABLE No. 5

**Variation of Oil Percentage on the Whole Seed in Early, Mid and Late Blooms of Flowering in Castor Strains H.C-1 & H.C-2 for 4 Years at Himayatsagar Farm.**

| S. No. | Year | Early | Mid | Late | Differences if significant |
|---|---|---|---|---|---|
| | | | H.C.-1 | | |
| 1. | 1940-41 .. | 49·00±1·71 | 48·40±1·10 | 46·70±2·20 | No. |
| 2. | 1941-42 .. | 40·30±1·55 | 47·61±0·43 | 48·30±1·18 | Mid and late superior to early |
| 3. | 1942-43 .. | 51·30±0·60 | 50·75±0·53 | 50·08±0·50 | Early and mid superior to late |
| 4. | 1946-47 .. | 45·10±3·87 | 44·46±5·50 | 44·68±5·13 | No. |
| | | | H.C-2 | | |
| 5. | 1940-41 .. | 47·45±1·10 | 48·31±0·56 | 40·94±1·57 | Early and mid superior to late |
| 6. | 1941-42 .. | 49·50±0·20 | 48·21±0·70 | 51·44±0·60 | Late and early superior to mid. |
| 7. | 1942-43 .. | 51·63±0·40 | 49·84±0·90 | 44·11±0·80 | Early and mid superior to late. |
| 8. | 1946-47 | 44·20±4·10 | 42·70±4·90 | 49·00±2·90 | No. |

The data show that in case of H.C.-1, the oil content does not vary from bloom to bloom, but in case of H.C-2, early and mid-blooms give more oil than late bloom.

### (3) Effect of Soil Fertility on the Oil content of Castor

Castor is raised on all types of soils. In the Telangana of Andhra Pradesh, it is grown on very poor sandy soils, while in Northern India it is raised on rich, alluvial soils. It is therefore interesting to know if the soil fertility has any effect on oil content. Experiments conducted at Himayatsagar gave the following results :

**TABLE No. 6**

**Oil Content Variation in Castor When Grown on Low and High Fertility Soils at Himayatsagar Farm.**

| S. No. | Kind of soil | Average oil per cent on whole seed | | If mean difference significant |
|---|---|---|---|---|
| | | H.C-1 | H.C-2 | |
| 1. | Siltyloam, depth 36″ .. | 47·30±0·85 | 46·82±0·45 | No. |
| 2. | Sandy chalka, depth 8″ | 48·00±0·41 | 46·14±0·62 | No. |
| 3. | Mean differences .. | 0·71±0·95 | 0·68±0·77 | No. |

Thus the oil content is not affected by fertility of soil.

Castor strains evolved at Himayatsagar Farm, Hyderabad, were on sandy chalka soils mentioned above. These strains were also tried in different parts of India with varying soil and climatic conditions. But everywhere the strains maintained their original oil content.

### (4) Oil content of Seed from Spikes of Different Orders

Castor produces a number of branches and each branch terminates in a spike. The most important orders are the main spike, the primary spike and the secondary spike. At Himayatsagar Farm, studies were conducted on H.C-1, H.C-2, and local castor. The results obtained are as follows :

*Mean Oil Content in Per Cent*

H.C-1 :

| | |
|---|---|
| Main spike | 52·52 ± 0·34 |
| Primary spike | 52·57 ± 0·34 |
| Secondary spike | 51·13 ± 0·55 |

Differences are not significant.

H.C-2 :

| | |
|---|---|
| Main spike. | 51·65 ± 0·50 |
| Primary spike | 49·85 ± 0·25 |
| Secondary spike | 50·17 ± 0·34 |

Differences are not significant.

Local :

| | |
|---|---|
| Main spike | 45·45 ± 0·62 |
| Primary spike | 44·57 ± 0·29 |
| Secondary spike | 45·64 ± 0·69 |

The main and primary spikes do not show significant differences. Similarly the main and the secondary do not show significant differences. But the primary and secondary spikes show significant differences.

## (5) Effect of Age and Different Methods of Storage on Oil Content of Castor

At Himayatsagar Farm, experiments were conducted by storing the seed of castor strains H.C-1 and H.C-2 in open trays, in gunny bags, in sealed kerosene tins and in glass jars. The first two methods are usually followed in warehouses and cultivators' houses while the last two are followed in laboratories.

Seed was stored on 18-10-1940. Quarterly analysis of each type was carried out from January 1941 to April 1943. The data obtained are given in Table No. 7.

**TABLE No. 7**

**Variation in Oil Content of Castor Strains H.C-1 and H.C-2 Stored in 4 Different Ways**

| Mode of storage | On Percentage of the whole seed and Month of Determination | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1941 | | | | 1942 | | | | 1943 | |
| | Jan. | April | July | Oct. | Jan. | April | July | Oct. | Jan. | April |
| | | | | | H.C-1 | | | | | |
| Tray .. | 49·41 | 48·50 | 48·68 | 48·04 | 49·19 | 50·21 | 47·63 | 47·32 | 42·75 | 47·56 |
| Bag .. | 48·44 | 49·40 | 47·23 | 48·45 | 45·94 | 46·02 | 48·23 | 45·27 | 44·81 | 42·01 |
| Tin .. | 49·19 | 47·74 | 48·42 | 49·25 | 48·56 | 44·77 | 45·76 | 49·51 | 48·08 | 47·06 |
| Jar .. | 51·04 | 45·59 | 45·51 | 50·80 | 49·01 | 47·93 | 48·67 | 48·39 | 52·56 | 47·99 |
| | | | | | H.C-2 | | | | | |
| Tray .. | 48·48 | 53·57 | 48·51 | 47·66 | 48·66 | 49·33 | 49·45 | 50·64 | 48·10 | 49·62 |
| Bag .. | 49·44 | 50·84 | 48·65 | 48·42 | 48·66 | 52·30 | 45·56 | 50·00 | 50·63 | 48·54 |
| Tin .. | 49·35 | 47·44 | 49·56 | 49·00 | 50·23 | 50·28 | 48·27 | 48·69 | 48·66 | 48·40 |
| Jar .. | 49·57 | 49·16 | 48·95 | 47·88 | 49·15 | 51·13 | 48·55 | 48·58 | 52·82 | 42·49 |

Even though the figures are somewhat erratic in certain cases, yet an overall conclusion is possible that the oil content does not go down with the age of seed nor does it go down if stored in open or closed containers. But the chemical composition of the oil was not studied and hence it is not certain if that is affected by age or mode of storage. In Madras, castor seed was stored in gunny bags. Even after 3 years, there was no deterioration either in free fatty acids or total oil content.

### (6) Effect of Degree of Maturity of Seed on Oil Content

The local castor varieties are usually shedding varieties. Hence, if the spike is allowed to stand till all the fruits are dry, there is a danger of some of them dehiscing and shedding the seed. So the cultivators usually harvest the spikes before all the fruits are dry. From the data presented under the heading "Determination of oil in seed from capsule discernibility to capusule maturity" it is clear that in fruits harvested before they are dry, full development of oil is not realised. At Himayatsagar Farm, studies were conducted on the determination of oil from harvests at different degrees of maturity. It was found that with one-fourth fruits on spike dry, the oil percentage of the spike is $45 \cdot 11 + 0 \cdot 311$ ; with half the number of fruits dry, it is $45 \cdot 13 \pm 1 \cdot 489$ ; with three-fourth dry, it is $47 \cdot 56 + 0 \cdot 368$ and with all fruits dry, it is $48 \cdot 39 + 0 \cdot 595$. It is therefore advisable to harvest when all fruits are dry, though for this it is necessary to grow non-shattering varieties. The chemical composition of oil with different degrees of maturity is worth studying. Since castor oil is largely used in industries, it is of the utmost importance to harvest the crop at the proper time. The oil content in relation to the method of harvest was studied at the Agricultural Research Station, Tindivanam (Madras). No difference was found in the oil content of produce harvested as and when the capsules became dry and that harvested when one or two capsules in a spike showed signs of drying and immediately dried in the sun. Both these treatments were superior to harvesting when a few capsules show signs of drying and heaping and weighting down the produce. The free fatty acids content was also the highest in the last treatment. The results show that it is not necessary to delay harvest till all the capsules in a spike are dry. The harvests can be taken up when one or two capsules show signs of drying but the produce must be immediately sun dried thoroughly.

### (7) Effect of Manuring of the Soil on Oil Content

To determine the economics of manuring castor with farm yard manure, groundnut cake and castor cake, experiments were conducted at Himayat-

sagar Farm. Incidentally, the oil content of seed under different treatments was determined, but there was no statistical significance between differences. Hence it was concluded that manuring of the field has no effect on oil content.

The data obtained are as follows :-

**TABLE No. 8**

**Variation in Oil Content of Strain H.C-2 Under Different Manuring Treatments**

| S.No. | Manure applied to the soil | Oil content (Percentage on whole seed) |
|---|---|---|
| 1. | Groundnut cake .. .. 0 | 48·60 |
| 2. | ,, ,, .. .. 20 lb. N. per acre | 50·66 |
| 3. | ,, ,, .. .. 40 ,, N. ,, ,, | 49·58 |
| 4. | Castor cake .. .. 0 ,, N. ,, ,, | 49·25 |
| 5. | ,, .. .. 20 ,, N. ,, ,, | 48·53 |
| 6. | ,, .. .. 40 ,, N. ,, ,, | 48·31 |
| 7. | Compost .. .. .. 0 ,, N. ,, ,, | 46·48 |
| 8. | ,, .. .. .. 20 ,, N. ,, ,, | 45·14 |
| 9. | ,, .. .. .. 40 ,, N. ,, ,, | 45·84 |
| 10. | F.Y.M. .. .. .. 0 ,, N. ,, ,, | 48·37 |
| 11. | ,, .. .. .. 20 ,, N. ,, ,, | 45·75 |
| 12. | ,, .. .. .. 40 ,, N. ,, ,, | 48·01 |

Ghosh [50] also observed that different manurial doses have no effect on the oil content of castor.

## (8) Variability of Oil Content

Taylor,[147] working in Bihar, maintains that oil content is very much affected by agricultural operations. Shaw, [129] Ghosh [50] report that climate does not affect the oil content of castor seed. Studies at Himayatsagar Farm reveal that none of the environmental factors like soil, climate, irrigations or drought conditions affects the oil content. At this station, a large number of lines with oil content ranging from 45% to 56% have been isolated and all these lines are constant for oil content. Just as morphological characters are observed every year to maintain the purity of strains, the oil content is also determined every year to see if any of the strains are deteriorating in oil content. But so far no strain of castor has been noticed to deteriorate in oil content. Strain H.C-1 was evolved at Himayatsagar Farm in 1939

with 51% oil content and this strain is still showing the same oil content, even in 1957.

Table No. 9 below gives the oil content of castor strain H.C-1 as determined in different years by random sampling. The number of plants analysed in each year is not constant but that does not affect the conclusions.

**TABLE No. 9**

**Oil Content of Castor Strain H.C-1 in Different Years**

| No. of the Plant analysed | Percentage of oil in whole seed | | | | |
|---|---|---|---|---|---|
| | 1937-38 | 1938-39 | 1939-40 | 1949-50 | 1951-52 |
| 1. .. .. .. | 50·8 | 55·82 | 50·70 | 49·8 | 50·4 |
| 2. .. .. | 50·4 | 54·41 | 52·65 | 52·7 | 52·8 |
| 3. .. .. .. | 53·4 | 55·24 | 55·99 | 53·7 | 54·0 |
| 4. .. .. .. | 49·7 | 48·90 | 46·38 | 50·5 | 51·6 |
| 5. .. .. .. | 51·6 | 51·10 | 42·88 | 53·6 | 51·4 |
| 6. .. .. .. | 51·9 | 50·85 | 47·66 | — | 53·4 |
| 7. .. .. .. | 53·3 | 51·11 | 53·94 | — | — |
| 8. .. .. .. | 53·51 | 53·53 | 54·89 | — | — |
| 9. .. .. .. | 51·80 | 52·00 | 51·93 | — | — |
| 10. .. .. .. | 52·60 | — | 54·59 | — | — |
| 11. .. .. .. | — | — | 51·98 | — | — |
| 12. .. .. .. | — | — | 51·39 | — | — |
| Average .. .. .. | 51·88 | 52·05 | 51·16 | 52·10 | 52·3 |

It is thus clear that oil content in castor is a constant varietal character.

CHAPTER VI

# ANATOMY, EMBRYOLOGY AND CYTOLOGY OF CASTOR

## I. Anatomy

Very little work on the anatomy of castor has been done. Pentfound[103] carried out anatomical studies on castor plants grown in different soils, moisture content and light intensity combinations. The root system showed better development in sunlight than in shadow despite greater leaf area. The development of the mechanical system was related to the intensity of light and soil moisture conditions. Scott [121] has studied the development of spiral vessels in detail. The development and distribution of calcium oxalate in mature green plants, etiolated plants, green and etiolated seedlings was also studied by her.[122] Reynolds [113] has made a detailed study of the development of node and the differentiation of the vascular network in castor. Scott and Sharsmith [120] have studied the transition region in the seedling of castor and have discussed the findings from a physiological standpoint. The following information is the outcome of the studies conducted at the Himayatsagar Farm :

(1) *Root* :— The root develops cork externally and the first phellogen originates in the cortex.

A single endodermal layer is present. The pericycle consists of strong thick-walled elements.

The xylem is tetrarch and is visible even after considerable secondary thickening. The secondary xylem is characterised by the presence of large diametered vessels. The entire wood is roughly divided into 4 sectors by fibrous zones. The rays are uniseriate. The vascular elements appear embedded in a sheet of fibrous tissue when observed in a transverse section.

(2) *Stem*:— The epidermis is single-layered with a cuticle, and is interrupted by large secretory cells which are filled in by oily or resinous substances. The epidermis shows an elevation over the secretory cells.

The hypodermis is collenchymatous in 8 or 9 layers, and is interrupted by a cortical zone consisting of plates of chlorenchyma.

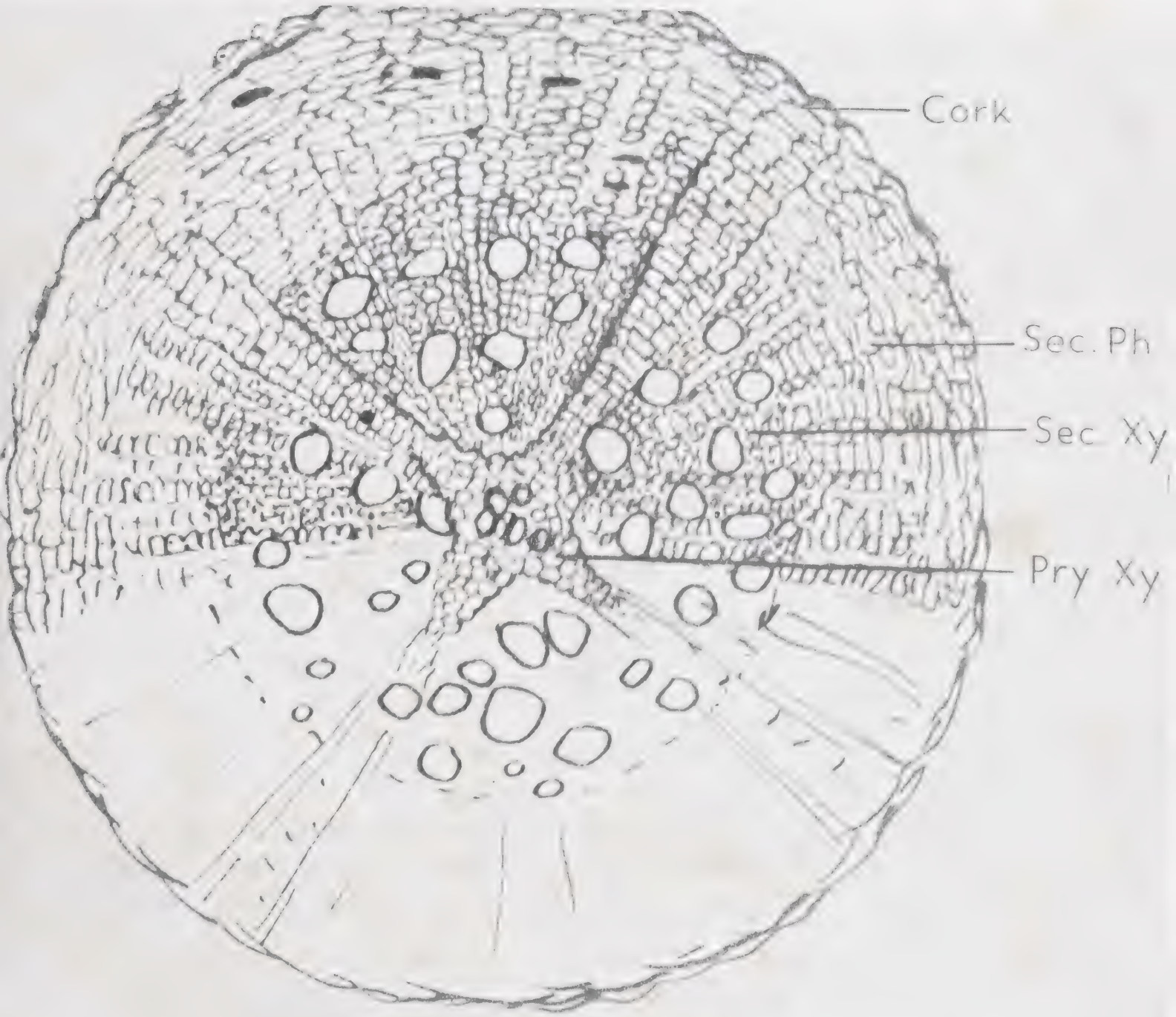


*Plate II — T. S. of root.*

*Plate III — T. S. of stem.*

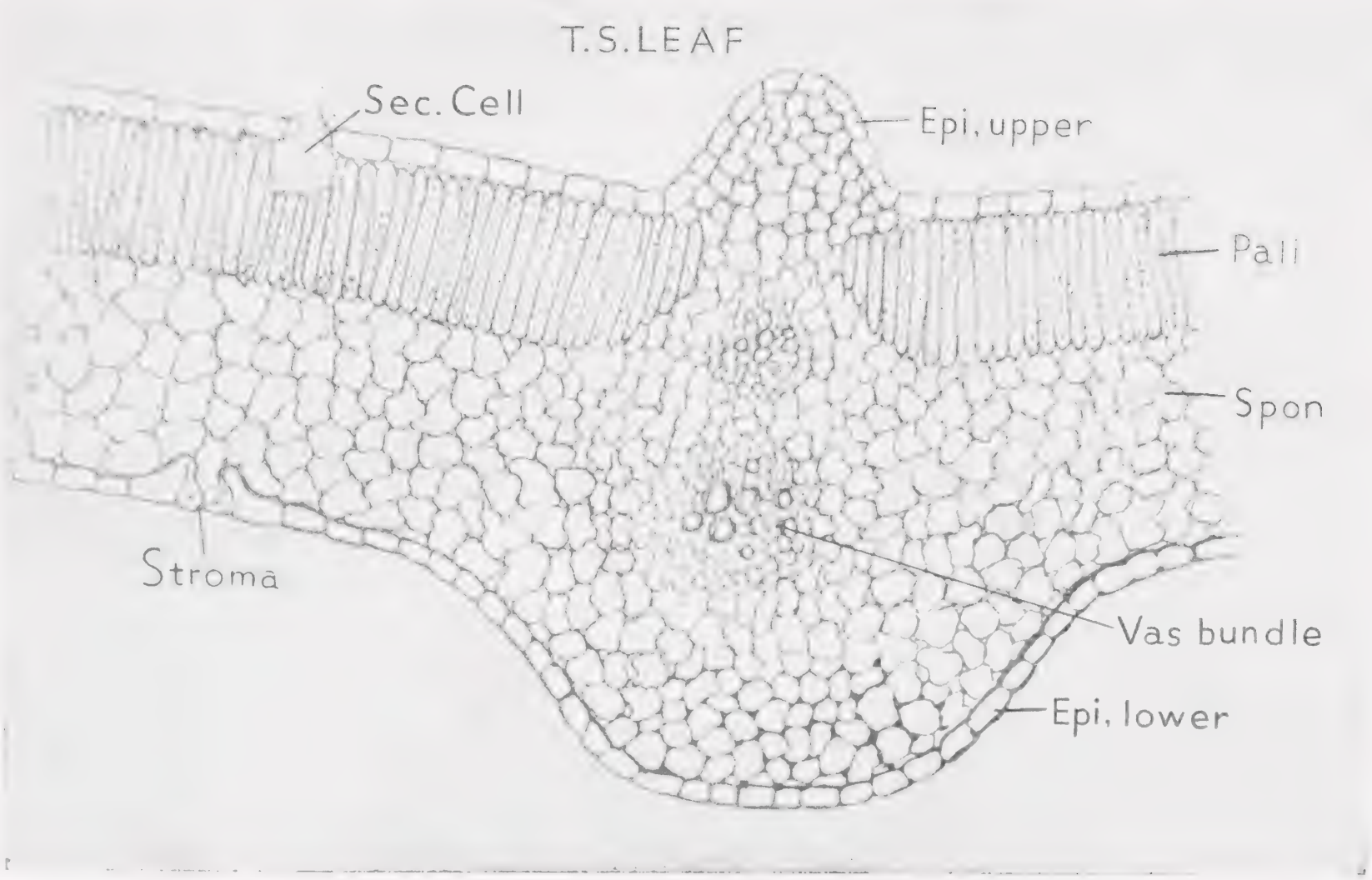


*Plate IV — T. S. of leaf.*

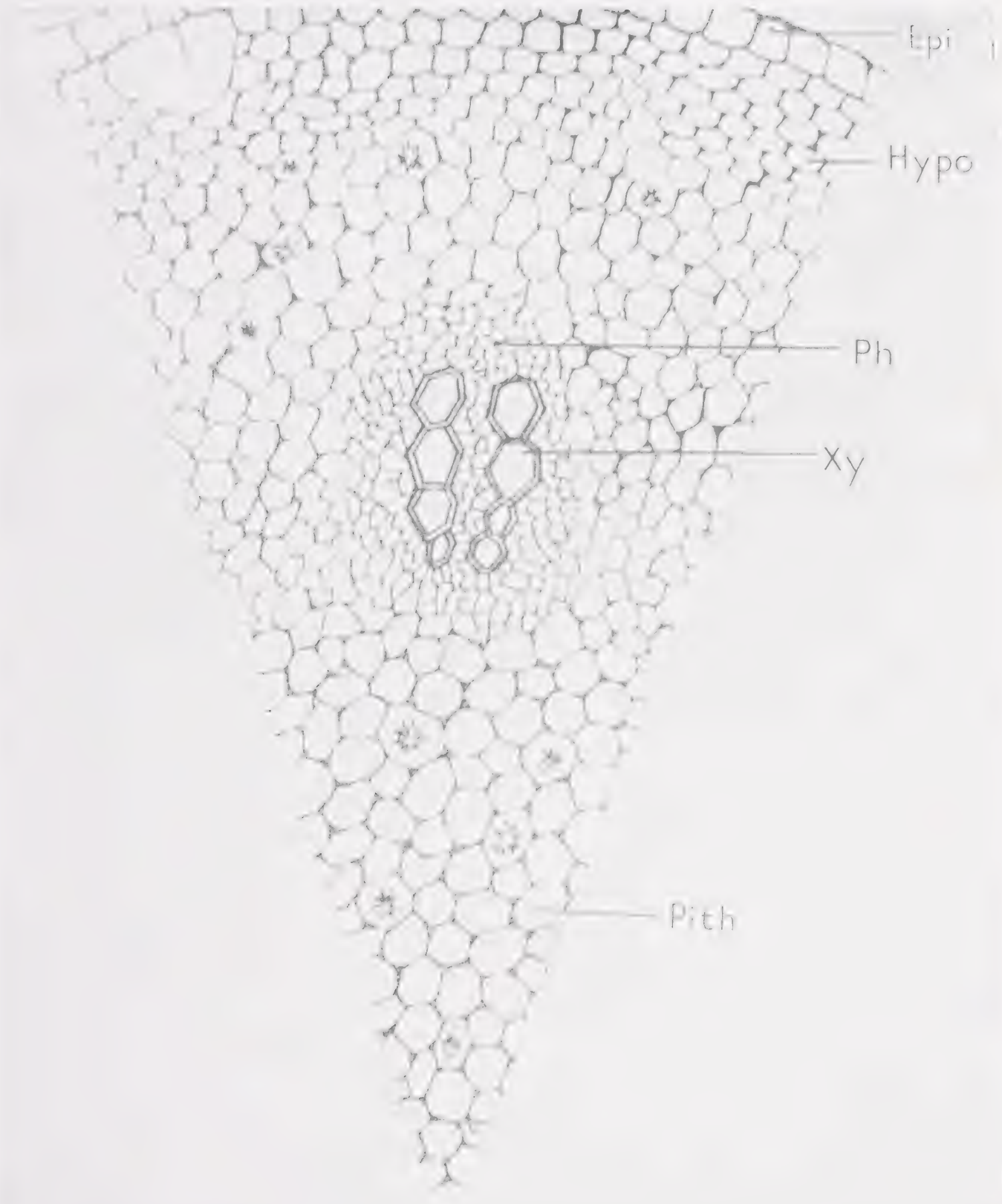


*Plate V — T. S. of petiole.*

This collenchymatous hypodermis is also interrupted by the large secretory cells.

The chlorenchymatous cortex is 5-6 layered with intercellular spaces. The endoderm is not clear. The pericycle as such, consisting of fibrous cells is not recognisable. The vascular system in the primary condition consists of conjoint, collateral bundles separated by medullary rays. The pith consists of polygonal parenchymatous cells.

John & Rao [69] report that the anatomy of the stem of seedlings of annual and perennial types revealed that the stem structure of perennial type differs from the annual type in that it has a more or less continuous cylinder of primary xylem ensheathed by an unbroken cylinder of secondary xylem, which is added on indefinitely. In the annual types, the vascular tissues are arranged in the form of discrete or discontinuous bundles in a cylinder.

(3) *Leaf* :— The leaf is bilateral. The upper and lower epidermis are interrupted here and there by secretory cells which are flask shaped. The palisade is single layered with elongated and small closely-abutting cells. The spongy tissue is relatively less interspaced.

In the transverse section of the petiole there are as many as eight vascular bundles running all along the length and in general the structure is very similar to that of the stem.

## II. Embryology

No mention is found in published literature about work on embryology. Maheswari [89] makes the following mention :

Regarding the final fate of the endosperm in *Ricinus*, it forms a permanent storage tissue which persists until the germination of seed, while in others it is used up by the growing embryo and is no longer seen in the mature seed.

## III. Cytology

Nemec (1910) reported the 2-n number in *R. zanzibariensis* as 20. Hagerup (1932) recorded 20 diploid chromosomes in *R. communis*. This number was confirmed by later workers and in the perennial types John and Rao[69] found the 2-n number to be 20.

According to Richharia[115] *Ricinus communis* is a secondary balance polyploid. Based on the maximum number of secondary associations the haploid constitution may be :

A A A

B B

C C

D D

E

The maximum number of secondary associations observed at I and II at metaphase is five.

Kurita[82] observed secondary association between two pairs of bivalents at metaphase.

Anubhava Narain[97] succeeded in *Ricinus communis*, by the application of 0·3 per cent colchicine solution, in inducing polyploidy in apical meristem and germinating seeds. Harland[61] and Peat[102] found that the factor for mahogany stem colour (M) and factor of bloom (B) are 8·3 units apart.

CHAPTER VII

# GENETICS OF CASTOR AND PRODUCTION OF SELFED AND PURE SEED

Castor is a very good material for genetic studies. It has a number of contrasting characters such as green and red stem, spiny and non-spiny fruits, size of fruit and seed, mottling on seed and oil content. But not much work has been done so far on the genetics of this crop.

## (1) Stem

White[165] classified stem colour into five categories :

(1) bright green, (2) green with reddish blush on sunny side, (3) carmine or rose-red, (4) mahogany red, and (5) purple or dark-red. He believed that development of red colour depends to some extent on sunlight.

In the studies at Himayatsagar Farm, it was observed that among the cultivated varieties there are two main colours : (1) faint red, and (2) green. These colours show also different degrees of intensity, depending on the bloom. If the stem is covered with bloom then the red and green colours of stem appear faint but if there is no bloom on stem then these colours appear bright. Green stem with reddish blush was found only in the $F_1$ of a cross between green X red. It was also observed that green-with-reddish-blush plants do not breed true and hence it is not a homozygous character. In the collections at Himayatsagar Farm, besides the red and green colours, there was also mahogany stem, pink stem, and sulphur-white stem.

The red pigment in the plant is soluble in water with traces of chloroform but not soluble in alcohol, xylol or pure chloroform. The red pigment is a sap colour occurring in epidermal palisade cells in the stem, and also in parenchymatous areas of the stem. The different shades of colour are due to differences in the amount of pigmented area of such cells. White[165] believes that the differences between the red types are due to presence and absence of several dilution factors, each of which affects the expression of red pigment.

In crosses between red-blush and green, $F_1$ was all red-blush and in $F_2$ there was a proportion of 3 red-blush : 1 green. In crosses red-blush x mahogany, $F_1$ was rose or carmine and $F_2$ gave 1 red : 2 rose : 1 maho-

gany (White[165]; Harland[60,62]). At Himayatsagar Farm, in a cross between red and green, the $F_1$ was all red with streaks of green and $F_2$ gave 1 red : 2 red with green streaks : 1 green. In $F_3$, red and green bred true but the reds with green streaks again split in the same ratio as in $F_2$. All this evidence clearly goes to show that the characters are determined by a single factor pair difference.

Harland[61] further found that in a cross between green and mahogany, $F_1$ was rose. From the $F_2$ results, he concluded that factor MG is green and Mg mahogany. Factor G converts tinged green into green and mahogany into rose. M is the factor for mahogany. Peat[102] confirmed the results so obtained by Harland. Patwardhan[101] in a cross between mineral green x blackish-red purple obtained $F_1$ with red stems. In $F_2$ all grades of colour, viz., blackish-red purple, pomegranate, diamine brown, hessian brown, pansy purple, and black-red purple were obtained. (The description of these colours is based on the Ridgeway Colour Standards, 1912, Washington). It was rather difficult to classify the colours, but when grouped as all colour grades except green : green, a good fit of 3:1 ratio was obtained. Seshadri and Varisai Muhammad (1951) reported that when two green-stemmed plants were crossed, the $F_1$ was red and the $F_2$ segregation was 9 red and 7 green. The green types have each a dominant complimentary factor which when, brought together, produce red colour.

### (2) Bloom on Castor

This has been fully described in the chapter dealing with morphology. White,[165] Harland[60,61] found that in crosses between bloom and no bloom, bloom is partially dominant and in $F_2$ a ratio of 3 bloom : 1 no bloom was obtained. Patwardhan[101] showed that bloom is intermediate in the $F_1$ and that triple bloom is dominant over double bloom.

Peat[102] found that in a cross between double bloom and no bloom, $F_1$ was with double bloom but the bloom was not as heavy as the parent. The $F_2$ gave 9 double bloom : 3 single bloom : 4 no bloom ; indicating that factors B and C together express the normal double bloom. C cannot express itself except in the presence of B. Thus the action of C is to merely intensify the action of B.

Further, in a series of families that were heterozygous for single bloom it was found that there was variation in the intensity of bloom. Some plants were with normal intensity of single bloom and some were with heavy single bloom. In the $F_2$ it was found that the characters differed by a single

factor. This factor is termed as 'D'. This factor intensifies the action of the factor 'B' for bloom.

(3) Leaves

Normal plants have leaves with lobes and lacination which is not very deep. In a cross, normal lacinated x deeply lacinated, Peat[102] obtained in $F_1$ plants with slightly more lacination than $P_1$. In $F_2$ the ratio fitted a monogenic difference.

Peat[102] also observed that albino colour is a simple recessive.

(4) Node number to first inflorescence

Peat[102] observed that the node number is greatly influenced by environmental factors. These observations were confirmed in studies by other workers in India. Masur[90] found that different types behave differently regarding the number of nodes to first inflorescence and the character was fairly constant and hereditary.

(5) Echinate nature of stem and petioles

Generally the stems of castor are smooth. A form from South Arcot had numerous small echinate protuberances on the stem, petioles and undersurface of mid ribs. Seshadri and Varisai Muhammad (1951) crossed smooth and echinate-stemmed plants. The $F_1$ was sparsely echinate showing incomplete dominance and the $F_2$ population segregated into 1 echinate, 2 sparsely-echinate and 1 smooth-stemmed plants.

(6) Colour of gland

There are two types of glands in castor—one yellow and the other red. Seshadri and Varisai Muhammad (1951) found the crimson colour to be dominant due to a single factor.

(7) Earliness

In a cross between early and late types, White [165] obtained intermediates in $F_1$ with all the three types in $F_2$.

In castor, it is rather difficult to specify what is early and what is late. In studies conducted at Himayatsagar Farm, it was found that the progeny of a pure strain do not all flower at one time nor even within a short range of three to four days. Even the flowering of the main spikes extends over weeks. The following shows the pattern of flowering in castor :

TABLE No. 10

Flowering in Castor

| Culture No. | Sept. | | October | | | | | November | | | | December | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 18 | 25 | 2 | 9 | 16 | 23 | 30 | 6 | 13 | 20 | 27 | 4 | 11 | 18 | 25 |
| 2180 .. | — | 1 | — | 2 | 2 | 8 | 10 | 5 | 2 | 1 | — | 3 | 6 | 5 | 4 |
| 2186 .. | 1 | — | 2 | 1 | 3 | 6 | 7 | — | 3 | 4 | 1 | 3 | 3 | 8 | 3 |
| 2205 .. | — | — | — | — | — | — | — | — | — | 1 | — | 2 | 4 | 6 | 4 |
| 2206 .. | — | — | — | — | — | — | — | — | — | 4 | 1 | 2 | 6 | 8 | 7 |
| 2211 .. | 1 | 6 | 1 | 1 | 3 | 1 | 1 | — | — | — | — | — | — | — | — |
| 2212 .. | 2 | 4 | 3 | — | 1 | 3 | — | 5 | 2 | — | — | — | — | — | — |

*Figures indicate the number of plants flowered.*

It may be possible to describe 2205 and 2206 as late flowering cultures while 2211 and 2212 are early cultures, but, if in $F_1$, a spread like 2180 or 2186 is obtained, it is difficult to classify the data.

### (8) 90 to 100 per cent Pistillate Flower Character

Katayama,[73] in the studies of inheritance of sex in gynodioecious strains, found that the female condition is determined by the gene 'a'; plants carrying 'A' being of normal monoecious type.

Classen and Hoffman[20] found that the character of the spike being 90 to 100 per cent female was controlled by one major recessive gene.

In case of castor, as described previously, the spikes are monoecious, but there are types where the entire length of the spike is full of pistillate flowers with only a few staminate flowers at the base of the peduncle. This character is very desirable in increasing production in castor. In a cross between such 100 per cent pistillate spike and local castor which has only 35 per cent pistillate flowers, the $F_1$ has spikes with 100 per cent pistillate flowers and in the $F_2$, all intermediate stages appeared.

Domingo[35] was able to obtain some flowerless plants in the $F_2$ population of crosses between normal parents. The $F_1$ flowered normally.

### (9) Compactness of Spike

In a cross of loose spike x compact spike, White[165] obtained $F_1$ with intermediates and loose. In $F_2$ both parents along with intermediates appeared.

(10) Colour of Fruit

Patwardhan[101] crossed normal green fruit with pink fruit and in $F_1$ obtained all green, and in $F_2$ a ratio of 3 green : 1 pink was obtained. Seshadri and Varisai Muhammad (1951) reported that in a cross between rose-red and green capsules, the $F_1$ was green and $F_2$ segregated in the ratio of 3 green and 1 coloured.

In a similar cross at Himayatsagar Farm, the $F_1$ was no doubt green, but the actual number of counts was :

| | |
|---|---|
| Pink | 44 |
| Normal green | 479 |
| Value of $X^2$ | 4·1 |
| Value of P | 0·05 |

The counts fit a 15 : 1 ratio.

In a similar cross between normal green fruit and sulphur-white fruit, the $F_1$ had normal green fruits and in the $F_2$ the counts were:

| | |
|---|---|
| Normal green | 103 |
| Sulphur-white | 12 |
| Value of $X^2$ | 3·4 |
| Value of P | 0·05 |

The counts fit a 15 : 1 ratio.

(11) Spiny and Spineless Fruits

Harland[62] obtained partial dominance in the $F_1$ of a cross between spiny and spineless fruit, but on the same inflorescence, he found fruits with varying number of spines.

Peat[102] obtained incomplete dominance in heterozygous state.

In a similar cross at Himayatsagar Farm, it was observed that spiny fruits have about 130 spines per fruit. In the $F_1$ the fruits had only 65 to 68 spines, the length of the spine remaining the same. In the $F_2$ the actual counts obtained were:

| | |
|---|---|
| Spiny | 32 |
| Intermediates | 42 |
| Non-spiny | 21 |
| Value of $X^2$ | 5·59 |
| Value of P | 0·05 |

The counts fit a 3 : 1 ratio for spiny : non-spiny. Seshadri and Varisai Muhammad (1951) reported that the echinate nature (spiny) is partially dominant over smooth.

### (12) Nature of Epicarp

Among the non-spiny groups there are varieties with smooth epicarp and others with very rugose, warty capsules. It was reported by Seshadri and Varisai Muhammad (1951) that warty nature was partially dominant and the $F_2$ segregated into 1 : 2 : 1 ratio.

### (13) Stalk of Capsule

The stalk of the capsule is sessile in some varieties, while it is elongated in certain others. Seshadri and Varisai Muhammad (1951) reported that the stalked character is monogenic with incomplete dominance over sessile.

### (14) Branching of the Stalk of the Capsule

Among the stalked capsules, there are forms with branched stalk and some others with non-branched stalk. Seshadri and Varisai Muhammad (1951) reported that branched stalk is partially dominant over non-branched stalked nature and in the $F_2$ generation 1 : 2 : 1 ratio was obtained thereby indicating monogenic nature.

### (15) Pollination in Castor

The castor inflorescence is a monoecious raceme bearing pistillate flowers at the top and staminate ones at the bottom. Naturally it is expected that such racemes will be highly cross-fertilised. But White[165] working at Brooklyn Gardens found natural cross-fertilisation in castor to be about 5·0 per cent.

Domingo,[34] working under conditions prevalent in Illinois found natural cross-fertilisation varying from 19 to 36 per cent. This may be due to vigorous air-movements.

Seshadri and Varisai Muhammad (1951) reported that under conditions existing at the Agricultural Research Station, Tindivanam (Madras) the percentage of natural crossing was 5 to 14.

At Himayatsagar Farm, natural cross-fertilisation was studied by both the alternate row method and concentric circle method. In the alternate row method, green stem and red stem were alternated in rows three feet

apart. In the concentric circle method, the centre was sown with red-stemmed plant seed. From the centre, circles were drawn at 5′, 10′, 15′, 20′, 25′ radius. On the circumference of each circle were planted green-stemmed plants. It was observed that in alternate row method 11 per cent natural cross-fertilisation occurred.

In the concentric circle method, at 5 feet radius, only 8 per cent natural cross-fertilisation was obtained and this too only towards the east and not in any other direction. This is because winds blow from West to East. In 10 feet and larger circles, no natural cross-fertilisation occurred. Further, it was also observed that plots separated from each other by about 300 yards and sown with pure strains, maintained their purity. Thus pure seed of strains of castor can be multiplied by sowing in isolated plots.

Weibel and Woodworth[162] state that under conditions prevailing in Illinois, planting separated by 10 rods showed no evidence of out-crossing. Meinders and Jones[93] found that at 5 rods, 21 per cent pollen was caught ; at 15 rods, 8 per cent ; at 25 rods 4 per cent ; 40 rods, 2 per cent and at 60 rods, 1 per cent. Thus beyond 60 rods or 840 feet, there is no risk of cross-pollination.

At Himayatsagar Farm, studies in vicinism were conducted by planting castor in distant isolated plots and erecting aeroscopes at distances of 100 feet in all directions. It was observed that pollen travels only in the windward direction and, when the sky is clear and wind is at an average speed of 13 miles per hour, pollen is carried to a distance of 900 feet. On rainy days this distance is reduced practically to zero.

### (16) Production of Selfed Seeds

White[165] suggests Manila paper bags of fair size to give sufficient space for the rapidly growing inflorescence. He suggests square-bottomed bags. Peat,[102] working under Trinidad conditions, found that young capsules got scorched, and suggests removing the bags as soon as fertilisation is over. At Kanpur, satisfactory seed setting was obtained even under craft paper bags, but muslin bags were the most satisfactory. At Tindivanam (Madras) the best method of selfing has been found to be covering the inflorescence just before the flower buds begin to open with a fine-meshed cloth bag and tying its ends to a bamboo stick in the ground close to the plant. These bags could be washed and used repeatedly and therefore are much cheaper than butter paper bags.

At Himayatsagar Farm, butter-paper bags were used; but young capsules get scorched if the temperatures are high. These bags also get torn very quickly even with small showers and hence constant changing of bags is needed. To self 1,000 plants, about two reams of butter paper are required. This provides for two changes of bags. The cost, including cost of paper and labour of bag-making, comes to Rs. 75. On an average, per plant 10 grammes of selfed seed is obtained. Thus the cost of producing large quantities of selfed seed becomes prohibitive.

Muslin bags gave better results. Small cages covered with muslin bag were put on the spike and the cage was tied to the base of peduncle. The cages are 8" in diameter and 14" in length. Fruit-setting was good and about 20 to 30 grammes selfed seed was secured at 12 annas per plant. Attempts were also made to cage the entire plant with muslin cloth. By this method, adequate ventilation is ensured and temperature variations also will not be great. At a time two to three spikes of the same plant get selfed and sibbed. This method causes no scorching and gives very satisfactory results. The cost of caging one plant comes to seven to eight rupees.

Studies were also conducted with different coloured paper as selfing bags. Table No. 11 gives the results.

TABLE No. 11

Effect of Selfing Bags of Different Types of Material on Fruit Formation in Castor

(Number of plants studied in each treatment were 20)

| S.No. | No. of burnt spikes | Per cent burning | Per cent fruit formation | Per cent over control fruit formation |
|---|---|---|---|---|
| 1. Butter paper (control) .. | 11 | 55 | 40·05 | 100·0 |
| 2. Muslin cloth .. | 2 | 10 | 75·70 | 189·01 |
| 3. Brown paper 40 lb. .. | 7 | 35 | 49·25 | 122·97 |
| 4. Brown paper 60 lb. .. | 7 | 35 | 58·65 | 146·44 |
| 5. Cellophane White .. | 12 | 60 | 38·65 | 69·50 |
| 6. ,, Red .. | 14 | 70 | 50·31 | 125·61 |
| 7. ,, Pink .. | 13 | 65 | 41·30 | 103·12 |
| 8. ,, Dark Green .. | 12 | 60 | 45·05 | 112·48 |
| 9. ,, Light ,, .. | 7 | 35 | 67·10 | 167·54 |
| 10. ,, Yellow .. | 8 | 40 | 72·10 | 180·02 |
| 11. ,, Blue .. | 8 | 40 | 63·95 | 159·67 |
| 12. ,, Orange .. | 13 | 65 | 59·30 | 148·06 |
| 13. White paper .. | 7 | 35 | 42·15 | 105·24 |

These studies were conducted for three years and results of all the three years are consistent. It is interesting to note that yellow cellophane gives the same set of fruits as muslin cloth bags and light green also gives a good set. White cellophane gives a very low set while white paper gives as good a set as butter paper. To overcome the disadvantages of continuous selfing and at the same time to take advantage of the presence of hybrid vigour in the crop, a method of maintaining vigour and purity of strains has been devised in Madras. In this method outstanding plants from composite block are tested under progeny row trials, and those giving yields over the general mean and at the same time maintaining their purity, are pooled together for maintaining composite blocks the next season. By this, maximum chance for cross-pollination is given and at the same time the poor progenies are eliminated. By this process it has been possible to increase the vigour and general level of yield of the strains.

CHAPTER VIII

# AGRICULTURAL ASPECTS

## (1) Climate

Castor is grown under very varied conditions of soil and climate. In India, it is raised on the poorest *chalka* (sandy) soils of the Telangana area of Andhra Pradesh, with 20 to 35 inches rainfall, and also on the rich alluvial soils of Uttar Pradesh with a rainfall of 25 to 35 inches. It is grown from sea level up to an elevation of 5000 to 7,000 feet but it cannot stand frost. The plant needs a hot dry climate for proper development of fruits and seed and also to facilitate harvesting and threshing. It also requires 15 to 20 inches of rainfall, under unirrigated conditions.

## (2) Soil

Castor can be raised practically on any type of soil. In the Telangana part of Andhra Pradesh, it is raised on *chalka* soils which are extremely sandy with hardly 10 per cent clay and very poor in plant food material and water-retention capacity. In Andhra and Madras, it is raised on red sandy loams in the chief castor-growing districts of Anantapur, Nellore, Kurnool, Guntur and Salem and also in sandy soils under irrigation. In Malabar and South Kanara it is cultivated in rice fields after rice is harvested, along with summer vegetables under irrigation. In Uttar Pradesh it is raised on heavy loams.

In general, castor can be raised on any type of soil provided it is well drained. Castor cannot stand 'wet foot' or water-logging. That is why castor cannot be successfully raised on heavy black cotton soils with a clay content of 80 to 90 per cent. Castor cannot also tolerate alkalinity of soil, but can grow on soils which are slightly acidic.

## (3) Preparatory tillage

For lighter soils, the land is ploughed in summer months and with the onset of pre-monsoon showers, the clods are crushed by a disc harrow or a blade harrow. In clay loams, only harrowing is done by blade harrows two to three times, to bring the soil to proper tilth.

Experience at Himayatsagar Farm has shown that in types of soils like *chalka*, which are hardly 6 to 12 inches deep, a good ploughing to a depth of 12 inches gives a good growth of crop.

(4) Sowing

In Telangana region of Andhra Pradesh, castor is usually sown behind a light plough, in furrows of four to five inches depth. The seed is dropped by hand. After this, a light plank is run over the field to cover the furrows and seed. Castor can also be sown by a seed drill. Another method is to drop the seed in the furrow opened through a bamboo tube held by hand about 4-5 feet behind the plough. This is called "Moghada."

(5) Time of Sowing

Castor is mostly raised as a *kharif* crop. The time of sowing varies from place to place depending upon the rainfall and sowing of other crops. The cultivator usually gives more importance to crops like, *jowar*, groundnut etc., and hence sows castor last. Usually this crop is sown as a rainy season crop in October, but in Himayatsagar Farm crop sown in October gets a heavy attack of jassids and yields are reduced. In Mysore, the crop is sown in April. In Junagadh, Nawanagar and Cutch, sowing is done in August-September. In Andhra Pradesh, the time of planting commences from the last week of June and ends by middle of August. In Madras castor is raised as monsoon crop from June-July. At Himayatsagar Farm in Andhra Pradesh experiments were conducted to determine the optimum time for planting of castor. Table No. 12 gives the data of this experiment.

**TABLE No. 12**

**Yield Obtained From Different Dates of Planting of Castor at Himayatsagar Farm.**

| Year and Control | Dates of planting with their yields in terms of per cent on control | | | | | | |
|---|---|---|---|---|---|---|---|
| 1. 1940-41 .. | June 22 | July 6 | July 20 | Aug. 3 | Aug. 17 | Aug. 31 | — |
| Control July, 20 | 164·79 | 127·67 | 100·00 | 72·63 | 56·06 | 25·29 | — |
| 2. 1941-42 .. | June 26 | July 10 | July 24 | Aug. 6 | Aug. 21 | Sept. 4 | — |
| Control July, 24 | 118·02 | 133·02 | 100·00 | 83·98 | 52·53 | 61·20 | — |
| 3. 1943-44 .. | June 23 | July 7 | July 21 | Aug. 4 | Aug. 18 | Sept. 2 | — |
| Control July, 21 | 89·55 | 5·84 | 100·00 | 343·10 | 187·90 | 210·10 | — |
| 4. 1944-45 .. | — | July 3 | July 18 | Aug. 1 | Aug. 16 | Aug. 31 | Sept. 15 |
| Control July, 18 | — | 119·56 | 100·00 | 97·82 | 119·56 | 54·31 | 32·60 |
| 5. 1945-46 .. | — | July 3 | July 18 | Aug. 2 | Aug. 17 | Sept. 1 | Sept. 17 |
| Control July, 18 | — | 125·15 | 100·00 | 83·83 | 56·30 | 50·30 | 41·91 |

It will be seen from the above data that planting done earlier than middle of July, which is treated as control, has yielded better. Planting done late in August is not beneficial.

### (6) Seed rate

The seed rate varies a good deal depending on size of seed, or whether the crop is annual or perennial. All over India, usually the medium-sized seed varieties are sown. In Telangana of Andhra Pradesh, farmers use 15 lb. seed rate per acre. In Uttar Pradesh 20 lb. per acre are used. Experiments conducted to determine the optimum seed rate for castor at Himayatsagar Farm gave the folowing data :-

TABLE No. 13

**Yield Data in Terms of Per Cent of Control Obtained in the Seed Rate Experiments Conducted at Himayatsagar Farm**

| S. No. | Seed rate used and the spacing adopted to suit it | 1943-44 | | 1944-45 | | 1945-46 | | Average for years | |
|---|---|---|---|---|---|---|---|---|---|
| | | Per acre yields in lb. | Per cent on control of 36" x 18" | Per acre yields in lb. | Per cent on control of 36" x 18" | Per acre yields in lb. | Per cent on control of 23" x 18" | Per acre yields in lb. | Per cent on control of 36" x 18" |
| 1. | 9 lb. 36" x 18" | 199·1 | 100·0 | 531·9 | 100·0 | 222·8 | 100·0 | 319·3 | 100·0 |
| 2. | 12 lb. 36" x 13·5" | 278·0 | 139·6 | 602·4 | 113·2 | 227·1 | 101·9 | 369·1 | 115·6 |
| 3. | 15 lb. 36" x 10·8" | 219·2 | 110·0 | 570·7 | 107·3 | 205·6 | 92·3 | 331·8 | 103·9 |
| 4. | 18 lb. 36" x 9" | 249·5 | 125·2 | 566·4 | 106·4 | 133·7 | 61·3 | 316·5 | 99·1 |

*N.B.—As the seed rate varies, number of seeds per acre varies and hence distance between plants also vary. This has been shown in bracket after seed rate.*

It will be seen that in all years a seed rate of 12 lb. gives the highest yield and 15 lb. seed rate comes as the next best. Hence cultivators are advised to adopt 12 lb. seed rate per acre. If the same seed is hand-dibbled, 8 to 9 lb. of seed per acre is sufficient.

### (7) Spacing

Castor is one of the crops which respond to environment very quickly. Branching in castor is very much affected by spacing. In row-sown crop, plants surrounded by gaps branch more profusely.

In Madras, workers have found 36" spacing either way to be the best for a pure crop of castor and 6 to 8 feet between rows and 2 to 3 feet between plants for mixed cropping. In Uttar Pradesh 36" between rows and 24" between plants for annual varieties, and 72" between rows and 48"-60" between plants for perennial varieties has been suggested. Workers in U.S.A., recommend a spacing of 18" to 20" between plants and 40" to 42" between rows. In Hyderabad, 36" between rows and 18" between plants has been found to be the best. The data obtained are as follows :-

TABLE No. 14

**Yield Data Obtained From Crop With Different Spacings**

| S. No. | Spacing | 1943-44 | | 1944-45 | | 1945-46 | | Average of 3 years | |
|---|---|---|---|---|---|---|---|---|---|
| | | Per acre yield in lb. | Per cent on control of 36" x 18' | Per acre yield in lb. | Per cent on control of 36" x 18" | Per acre yield in lb. | Per cent on control of 36' x 18" | Per acre yield in lb. | Per cent on control of 36" x 18" |
| 1. | 24" x 18" | 496·3 | 86·0 | 258·6 | 119·4 | 252·7 | 71·51 | 335·8 | 88·60 |
| 2. | 36" x 18" | 573·3 | 100·0 | 216·6 | 100·0 | 354·4 | 100·0 | 381·3 | 100·0 |
| 3. | 48" x 18" | 530·6 | 92·6 | 164·6 | 76·0 | 275·6 | 77·74 | 323·6 | 84·80 |
| 4. | 60" x 18" | 475·1 | 82·9 | 235·0 | 108·5 | 159·1 | 44·80 | 289·7 | 75·90 |
| 5. | 72" x 18" | 479·2 | 83·6 | 185·1 | 85·4 | 147·7 | 41·84 | 270·7 | 70·90 |

## (8) Irrigation

Castor is raised usually as a rainfed crop as it is very hardy and drought-resistant; and it can thrive very well even with 20 inches rainfall. Hence the question of irrigating castor does not arise.

In Bombay and Madras States, castor is sometimes planted to serve as wind breaks, along the borders of sugarcane fields which are heavily manured and irrigated. The effect of this environment is to make the castor plants grow almost like trees and branch profusely. Castor does respond favourably to irrigation.

## (9) Manuring

In the 19th Century, there was a belief that castor is not an exhausting crop and in America, it was even thought at one time that a castor crop added fertility to the land (Turner 148). Ercole [15] reports a similar belief and refers to the system of renting land free for cultivation of castor in Australia. But recent experiments have shown that castor does not add any fertility to the soil. In certain parts of the castor belt of Telangana in Andhra Pradesh, the lands are so poor in fertility that no other crop except castor can be raised on such soils. The cultivator has been raising castor year after year on such soils for generations and still the soils have remained poor in fertility.

Highly fertile soils with high nitrogen content are not suitable for castor. Such soils produce excessive vegetative growth and very tall plants that are di-

fficult to harvest. Soils of average fertility are best suited for castor. Domingo and Crooks [86] reported that fertiliser tests in Kansas, Kentucky, Mississippi, Missouri and Oklahama, failed to show any marked increase in yield from nitrogen, phosphorus, or potassium either alone or in combination on the conner variety of castor. The only significant increase from any treatment was with phosphorus alone at Princeton, Kentucky. In the same test, phosphorus with nitrogen and potassium failed to produce any significant increase. However, in view of the fact that castor plant grows very rapidly, it is considered to require a soil in which the nutrients are readily available. Although its nutrient uptake is not very much, an application of about 18 to 36 lb. of nitrogen, 45 to 63 lb. of phosphoric acid and 45 to 67 lb. of potash per acre has given encouraging results.

In India, Ghosh [50] obtained significant increases in yield with the addition of organic and inorganic manures. In Uttar Pradesh Sethi [127] obtained increased yields by application of farm-yard manure.

In Andhra Pradesh at Himayatsagar Farm, experiments were conducted to study the effect of locally available cheap manures like farm-yard manure compost, castor cake and groundnut cake on the seed yield of castor, the residual effect of these manures and the economics of such manuring also. The study revealed the following points :-

(a) The application of 30 lb. N in the form of farm-yard manure or castor cake results in increased seed yields.

(b) The quantity of N content of the manure controls the quantity of manure to be applied, which, in turn, controls the costs and the resulting profit or loss.

(c) The prevailing price rate of castor seed is the controlling factor in deciding the profit or otherwise from the manures used.

(d) The beneficial residual effects of manures continue for two years at decreasing levels.

The increase in yield in the first year of manuring is about 30 lb. per acre, in the second year on the same plots 230 lb. and in the third year again on the same plots 400 lb. In the fourth year or first year of residual effect, though the increase over control is 110 lb. per acre, yet it is a great fall from 400 lb. increase obtained in the third year of manuring. In the fifth year or second year of residual effect, the increase is only 50 lbs. Another im-

portant point noted was that the residual effect of compost and farm-yard manure lasts longer than cake manures.

In general, it does not pay to manure castor immediately, but in the long run it may be helpful to maintain soil fertility.

## 10 Mixed cropping in castor

Castor is raised both as a mixed crop and as a pure crop. In Bihar, it is sown mixed with black gram, or with horse gram. As a *kharif* crop, it is sown mixed with maize, red gram or cotton and as a *rabi* crop with mustard, peas, potatoes and chillies. In Nawanagar, Junagadh and Cutch, gram, *sesamum* and cotton are the common mixtures with castor. In Bombay, it is sown as a mixture with *jowar*, *bajra* and *sesamum*. In Andhra part of Andhra Pradesh, castor is sown mixed with *jowar*, *bajra*, groundnut, *ragi*. In Mysore, castor is mixed with chillies, *ragi* and beans. In the northern districts of Uttar Pradesh, castor is mixed with maize or red gram and in southern districts with *jowar*, *bajra* and cotton. Castor mixed with cowpeas is raised at Kalianpur Research Station, Kanpur. In Madras castor is generally raised as a mixture with groundnut. Mixed cropping experiments at the Agricultural Research Station, Tindivanam (Madras) have shown that this is a profitable method of cropping. Recent experiments have shown that castor lab-lab mixture is also profitable. Castor is raised under irrigation as a border crop in sugarcane and betelvine fields and as a shade crop in chillies and turmeric.

In general, it may be stated that the mixtures mentioned above are not mixtures in the sense of raising two crops in a certain proportion. Usually castor is sprinkled in a field where some major crop like, *jowar*, *bajra*, red gram, chillies etc., is going to be raised, and so the proportion of castor to be sown with other crops is always indefinite.

At Himayatsagar Farm, experiments were conducted raising castor alone, and as a mixture with groundnut, *jowar* and maize. In case of groundnut and castor mixture, after 2 rows of castor, 2 rows of groundnut were planted. In case of *jowar* and maize, after 3 rows of castor, 2 rows of either *jowar* or maize were planted. The experiment clearly showed that groundnut could be raised after a few rows of castor but *jowar* and maize cannot be grown as rows after a few rows of castor. As far as the castor tract of Telangana, Andhra Pradesh, is concerned, it is profitable to raise castor only as a pure crop.

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## 11 Intercultivation

Frequent intercultivation is necessary till the plants attain a height of three feet and cover up the interspaces. In a pure crop where sowings have been done in lines, working a junior hoe or a blade harrow in both directions is efficient and cheap. Even ploughing between lines is resorted to in some cases. Removing weeds around plants is done with manual labour and this is essential as such weeds harbour pests like semi-looper. In mixed cropping the intercultivation given to the main crop, benefits castor also.

## 12 Harvesting

As castor plant is branching type, it produces three to four spikes on each plant at different intervals. The main stem terminates in a spike and this is known as the main spike. This is followed by side spikes which get ready for harvest at different intervals. Usually, the main spike gets dry in about 180 days after sowing. Thus in Telangana of Andhra Pradesh where castor is sown from the end of June to middle of July, the first harvest is ready by December or early in January. Then at intervals of 20 days, another two to three harvests get ready and thus by the end of March *i.e.*, in about 240 days after sowing, the plant gets completely dry.

The local castor varieties raised by cultivators have shattering capsules. Hence, the cultivator does not wait till all the fruits on a spike are fully dry. When one or two fruits are dry, he plucks the spike and makes a heap and sprinkles it with cowdung mixed in water. Due to the heat so created, the fruits dry up quickly. In northern India, capsules are put in a pit and covered with cowdung and earth, for three to four days. All these methods reduce the oil content as already explained under Chapter V. Workers in Madras also have found that, by harvesting capsules before they are fully dry, both the oil content and the quality of the oil are impaired.

With the advent of improved strains, there is no more necessity of harvesting the spikes when fruits are not fully dry. All the strains evolved at Himayatsagar Farm and similar other strains evolved by other States are non-shattering. By sowing such improved strains, farmers can wait till the entire spike is dry and then harvest the capsules. With non-shattering strains of castor, experiments were conducted at Himayatsagar Farm to see if the harvests could be reduced to two. The first harvest was effected in mid-January when the main spikes as well as the spikes on primary branches were completely dry. The second harvest was done by the end of March, when

all the remaining spikes were dry. It was observed that the fruits do not shatter but the entire dry fruits fall down 15 days after the spike is fully dry.

In U.S.A., small-stemmed, non-shattering varieties of uniform maturity have been evolved to enable the crop to be harvested by machines.

## 13 Hulling

In India, threshing is done by beating the dried fruits with a stick or sometimes under the feet of bullocks. After threshing, winnowing is done in the usual way. No machinery is used in India. In the U.S.A., hulling machines are now available.

The proportion of seed to husk was studied at Himayatsagar Farm and the data obtained are as follows :—

**TABLE No. 15**

**Proportion of Seed to Husk in Castor**

| S. No. | Date of picking | Weight in lb. | | Proportion of seed |
|---|---|---|---|---|
| | | Capsules | Seed | |
| 1. | 29-11-1938 .. .. .. .. | 37·0 | 22·0 | 59·45 % |
| 2. | 14-12-1938 .. .. .. .. | 49·0 | 28·0 | 57·14 % |
| 3. | 8- 1-1939 .. .. .. .. | 165·0 | 95·0 | 57·51 % |
| 4. | 6- 2-1939 .. .. .. .. | 505·0 | 276·0 | 54·65 % |
| 5. | 18- 2-1939 .. .. .. .. | 240·0 | 137·0 | 57·08 % |
| 6. | 8- 3-1939 .. .. .. .. | 178·0 | 93·0 | 52·24 % |
| 7. | 23- 3-1939 .. .. .. .. | 225·0 | 57·0 | 25·33 % |
| | Total .. .. .. .. | 1313·0 | 658·0 | 50·11 % Average |

The data clearly show that in the first picking, the proportion of seed is the highest; this goes down in the sixth picking when it is only 52·24%, while the last picking gives only 25·33 per cent seed. From November onwards the rains cease. The moisture available in the soil is utilised till February, but by March, the heat increases and the soils get quite dry. This might be one of the reasons for the proportion of seed going down so much.

## 14 Yield of Castor

As reported before, castor is sensitive to environment and hence the yields are highly variable. In Mysore State, the yields are 140 lb. per

acre. In Nalgonda district of Andhra Pradesh where soils are very sandy, castor yields are 160 lb. per acre. In Uttar Pradesh, on alluvial soils, the yields are more than 500 lb. per acre. In Manchukuo, the yields are the same as in Uttar Pradesh. In Brazil, where castor is raised along the banks of rivers, the yields are 2,200 lb. per acre but in California, yields have been recorded up to 3,000 lb. per acre, with improved strains. The recently evolved hybrid castor seeds have reported to have given yields upto 5,000 lb. in America. The average yield for India, however, is only 206 lb. per acre. At the Agricultural Research Station, Tindivanam (Madras) in years of well-distributed rainfall average acre yield of 800 lb. have been obtained from the departmental strains under improved methods of cultivation.

Castor stalks when completely dry weigh about 150 lb. per acre, with a crop height of 3 to 4 feet.

### 15 Storage of Castor

Castor seed is very hard and does not require much care during storage. No insect or disease attacks the seed. The oil content does not get either reduced or affected even after 3 years of storage. (Please refer Chapter V). Usually castor seed is not required to be stored in warehouses over long periods. Being a cash crop, it is immediately exported or crushed locally and the oil exported. In warehouses, castor seed is stored in (jute) gunny bags.

Sometimes if the bags get wet due to high humidity or leakage of rain water, the seeds become slightly mouldy but this does not reduce the oil content or the viability.

### 16 Dormancy in Castor Seed

Studies at Himayatsagar Farm, revealed that in case of castor seed there is no dormancy, as the seeds could be sown immediately after harvest with equally good results. No resting period is needed.

### 17 Germination and Viability of Seed

Experiments have shown that seed as old as four years gives 60 per cent germination. Experiments at Himayatsagar Farm have shown that, if the seed-coat is removed, germination is quicker. Germination commences within 70 hours and is usually completed in seven to nine days. The next best is soaking the seed in water for 12 hours. In this case, germination starts within 120 hours. But in all cases the pre-requisite is adequate moisture in the soil at the time of sowing.

## 18 Cost of Cultivation of Castor

This will vary from State to State depending upon the rates of wages and the type of cultivation followed. In Andhra Pradesh, Bombay, Madhya Pradesh and Mysore, castor is raised on lighter types of soils and method of cultivation is fairly uniform. The following estimates will give an idea of the cost of cultivation per acre in the Deccan :—

**TABLE No. 16**

**Cost of Cultivation of Castor**

| Item of work | Details per acre | | | | Cost |
|---|---|---|---|---|---|
| | Bullocks | Men | Women | days | Rs. |
| Ploughing .. .. .. .. .. | 2 | 1 | — | 2 | 7- 8-0 |
| Harrowing by blade harrow .. .. | 2 | 1 | — | ½ | 1-14-0 |
| ,, ,, ,, ,, .. .. | 2 | 1 | — | ½ | 1-14-0 |
| Running of plank .. .. .. .. | 2 | 1 | — | ¼ | 0-15-0 |
| Cost of seed 12 lb. .. .. .. .. | — | — | — | — | 2- 8-0 |
| Sowing .. .. .. .. .. | 2 | 1 | 2 | ½ | 2-10-0 |
| One hand weeding .. .. .. | — | — | 10 | 1 | 7- 8-0 |
| One bullock hoeing, cross-wise .. .. | 2 | 1 | — | 1 | 3-12-0 |
| Harvesting .. .. .. .. | — | — | 8 | 1 | 6- 0-0 |
| Harvesting .. .. .. .. | — | — | 8 | 1 | 6- 0-0 |
| Harvesting .. .. .. .. | — | — | 8 | 1 | 6- 0-0 |
| Threshing .. .. .. .. | — | — | 4 | 1 | 3- 0-0 |
| | | | | Total | 49- 1-0 |

Rates of wages :—

Man Rs. 1-4-0 per day.

Woman ,, 0-12-0 per day.

Bullocks ,, 2-8-0 per pair.

Yield of seed per acre 250 lb.

Price of castor seed Rs. 50 per *palla* of 250 lb.

Value of produce per acre Rs. 50.

It will thus be seen that what the cultivator realises from castor is just his own wages. Profit depends entirely on the market rate of castor.

CHAPTER IX

# BREEDING WORK IN CASTOR AND EVOLVING VARIETIES

(1) *U.S.A :*—The first country to start crop improvement work on castor was U.S.A., at the Brooklyn Botanical Gardens, New York and Oklahama in 1902. White [165] and Shaw [129] collected a large number of samples and were carrying out selection work. Shaw believed that, by mere selection, pure lines with higher oil content could be isolated, but, no intensive work was carried out in those early days. Between 1941 and 1943, intensive work on castor was taken up at 22 different States and it is now being carried out at the Bureau of Plant Industry Station, Beltsville, Maryland ; the University of Nebraska ; Louisiana State University ; the Illinois Agricultural Experiment Station and the Oklahama Agricultural Experiment Station.

In the U.S.A., the problem was of combining the characters of earliness, short plant and non-shattering character. The scientists have been able to evolve varieties combining all these desirable qualities.

Emasculation was achieved in two ways—one by rubbing off the staminate flowers by finger and thumb and the other by using forceps. Emasculation requires two visits to the plant. When plot consists of plants flowering at different periods, emasculation lasts several weeks. However, as soon as sufficient seed was formed on any given seed parent, all later-formed spikes were removed.

White[164,165] suggested a simple and rapid method of hand-pollination, by rubbing off the staminate flowers by thumb. When pollen parents' spikes are mature, they may be cut and kept on paper till the flowers shed pollen. This pollen is then put in a powder gun and shot over the pistillate parent.

White's method is useful where there are no winds. But with high winds blowing, Weibel and Woodworth's method is preferable.

Exploitation of hybrid vigour has recently been taken up for further improving the strains. Weibel and Woodworth [141] suggested the use of natural crossing plots for production of hybrid at Illinois. In the case of castor, the plant is mainly wind-pollinated. Secondly, the staminate and pistillate flowers are borne on distinct regions of the spike and the former can easily be removed before they shed pollen. The pollen and seed parents were planted

in alternate rows. The pollen parent was planted in each outside row as well as in alternate rows, but not across the ends of rows. Small plots were used consisting of 10 to 14 rows, 40 inches apart and 2 rods length. Plants, both in male and female rows, were spaced 20 inches apart.

The improved varieties in U.S.A., are Conver and Kansas giving an oil content of 53·05 and 53·20 per cent respectively.

(2) *U.S.S.R :*—Work on castor commenced in 1930. Here too, the problem is to have early and non-shattering types. For early types, the Manchurian variety that matures in 75-85 days forms a good parent. The Persian type with a single spike is found to be most productive in the U.S.S.R.

In 1939, some samples were received from the U.S.S.R. at Himayatsagar Farm but the oil content of the seed received was hardly 40 per cent and the plants did not thrive well.

(3) *Brazil :*—Intensive work was started at the State Agronomic Institute of Sao Paulo. By selection alone, lines were isolated for (1) combination of desirable characters, (2) yield only (3) high oil content only, and (4) spike length. Hybridisation has also been resorted to. Numbers 14, 38 and 45 are the most promising strains.

(4) *Italy :*—Dionigi [31] started work on castor in 1934. He collected a large number of samples and by selection and hybridisation, evolved a strain M 6, which has proved very promising. It matures in 100 days. It is short with low inflorescence. At Naples, work on castor was begun in 1948 by Laggieri. Here too, by selection alone, lines with 51·9 per cent oil have been evolved. These lines are also drought-resistant.

(5) *France :*—Work on castor is going on at the Central Plant Breeding Station, Versailles. Chonard [18] reports that by treating castor pollen in a electro-magnetic field, very useful mutants have been obtained. The capsules of the new variety have thin walls and are non-dehiscent.

(6) *South Africa :*—In the Transvaal near Johannesburg and Pretoria, Dr. Ott E. Knapp was working on castor for over 20 years. His work was based on material collected from Italy, India, Manchuria, Africa, Brazil and Russia.

All the improved varieties are non-spiny, non-shattering, and short in height. The breeding and selection work under the extreme climatic conditions of the Transvaal (6,000 feet above sea level with hot summers and cold winters) has produced annual varieties which are very resistant to drought.

They also have a certain degree of resistance to *Alternaria ricini*. These varieties were found suitable in Angola, Mozambique and Tanganyika and potentially of great importance to countries like Rhodesia, Ethiopia, Congo, Pakistan, India and Iran. Unfortunately, Dr. Knapp was not in a position to continue the breeding work after 1955 and as such the fate of all the valuable material collected by Dr. Knapp is not known.

(7) *Castor Breeding in India* :—In India, castor breeding work is going on at Kanpur in Uttar Pradesh, at Tindivanum in Madras, at Hebbal in Mysore, at Surat in Bombay, at Jullundur in the Punjab and at Himayatsagar Farm in Andhra Pradesh.

(*a*) *Madras* :—Madras has an area of about 36,000 acres under castor and produces about 6,000 tons of seed annually. Selections are made from new acquisitions and after purification for morphological characters, they are tried out in yield tests. Characters like good branching, long fruit clusters, resistance to pests and diseases, shorter duration etc., are specially sought for.

Crosses have been effected between desirable parents and selection made from $F_3$ and $F_4$ generations. The promising material is first tried in preliminary tests in plots of 69′ x 9′. Material found superior in such tests is then tried in large-scale yield trials with a plot size of 69′ x 15′. Finally the best material is tried on cultivators' fields.

As an outcome of such work, Madras has evolved strains TMV. 1, TMV. 2 and TMV. 3, that are capable of yielding 20 to 30 per cent more seed over local. Three more promising types, namely, R. C-1074, R. C-1075 and R. C-1076 with much shorter durations have also been recently isolated. A perennial castor strain CO.1 isolated is found useful for cultivation in higher elevations and in places where irrigation facilities are available. Eight ornamental types of castors have also been isolated. They are showy types suitable for cultivation in gardens. This station is also carrying out studies on spacing, storage, roots, cytology and inheritance of characters. These have been described under appropriate chapters.

(*b*) *East Punjab* :—There are hardly 1,000 acres under castor in the Punjab, but there are possibilities for increasing the area both on the plains and at higher elevations. There is great scope for perennial castor and hence at Jullundur and Nagrota, a large number of perennial castor samples are under study.

There is also great scope for *Eri* silk worm industry and for this, castor leaves are indispensable. But defoliation for rearing *Eri* silk worms was

found to arrest the growth, delay flowering and reduce the yield by about half in an experiment at the Agricultural Research Station, Tindivanam (Madras).

Himayatsagar castor strains H.C-2 and H. C-5 have been found quite suitable to this tract.

(*c*) *Bombay* :—The area under castor in this State is about 1,71,000 acres, with an annual production of about 26,000 tons of castor seed. Of this total area, nearly 1,23,000 acres are in Gujarat alone.

Breeding work on castor was started in 1925 at Nadiad in Gujarat, but has now been discontinued. As an outcome of the work done, two strains S-5 and S-20 have been evolved and are now under trial.

(*d*) *Mysore* :—The State has an area of 94,000 acres under castor and produces annually 7,000 tons of castor seed. Castor breeding work has been taken up at Hiriyur, Hebbal and Mandya. The work consists mainly in testing the strains evolved by other States.

(*e*) *Uttar Pradesh* :—The area under castor in Uttar Pradesh is less than 7,000 acres, with an annual production of 1,000 tons of castor seed. It seems that the crop is grown as mixture with other crops and along the borders of fields. A large number of varieties have been collected and are being studied. Type E. C-2178 is the smallest-seeded, with a weight of 16·5 grm. per 100 seeds, while N. S-1948 has the boldest seed with 90·7 grm. per 100 seeds. E. C-1514 is the earliest type flowering in 28 days after seeding, while type 5211 is the latest, requiring 115 days for flowering. Type 3 has been found to be superior and its seed is under multiplication and distribution.

(*f*) *Telangana of Andhra Pradesh* :—Work on castor commenced in 1929 and was carried out on a small scale till 1935 when the I.C.A.R., sanctioned a scheme for work on castor at Himayatsagar Farm. At the outset, 130 samples from all over India were collected. To these were added samples collected locally. From 1935 to 1955, total number of new samples collected and studied is 617. In the beginning the work was confined to selection alone. It was noticed that in the local castor, more than 50 per cent of the spike is occupied by staminate flowers and hence no fruits are formed on this portion. Fruit formation is thus restricted to 50 per cent or less of the portion where pistillate flowers are formed. Hence, attention was concentrated on isolating plants with spikes having the maximum pistillate flowers possible. The second important character, naturally, was yield and the third was oil content. In the earlier stages, as many as 200 lines, each with a progeny

of 50 plants were under intensive study. From the commencement of selection work, seed of large number of desirable plants was analysed for oil and selection was based on the data collected. The oil content of local castor is 46 per cent on whole seed and seed yield is about 220 lb. per acre. As an outcome of early selection work, castor strains H. C-1, H. C-2, H. C-3 and H. C-4 were evolved by 1939. Their seed yield, oil content and seed size are as follows :—

**TABLE No. 17**

**Some Important Characters of Strains H.C-1 to H.C-4 and Local**

| Material | Seed yield per acre in lb. | Oil content per cent on whole seed | Plant characters. |
|---|---|---|---|
| H. C-1 .. | 300 | 51 % | Green, triple bloom, non-spiny |
| H. C-2 .. | 300 | 48 % | Green, triple bloom, spiny |
| H. C-3 .. | 300 | 48 % | Red, triple bloom, spiny |
| H. C-4 .. | 300 | 48 % | Red, triple bloom, spiny |
| Local .. | 220 | 46 % | Red, double bloom, spiny |

Thus H. C-1 is the best. This variety is also green, triple bloom, non-spiny with seed type slightly bolder than local and spikes mostly female, *i.e.*, almost the entire length of peduncle is covered by pistillate flowers with only a few staminate flowers at the base. This variety was released to the farmers.

With a view to convince the oil mill owners and trade agents about the superiority of H. C-1 over the local types and thus induce them to offer a premium over local, large scale oil extraction tests were conducted in oil mills and the buyers were thus convinced. But the middlemen who buy from cultivators by volume, found that H. C-1, volume for volume, weighs less than the local and so they would not accept H. C-1 produce. Traders and agents would not offer premium unless large quantities come to market. Thus in spite of evolving a better strain, it could not be spread, as the cultivator wanted that the seed of improved strains should be just like the local. The seed of strains H. C-1, H. C-2, H. C-3, H. C-4 and local was also sent to Ralli Brothers, Swastik Oil Mills and Volkart Brothers for oil extraction and trade evaluation. All these firms uniformly preferred H. C-1 and offered to pay premiums over local.

Further selection was continued and by 1943-44, a new set of strains namely, H.C-5, H.C-6 and H.C-7 with seed type just like the local, spikes

mostly female, just as H. C-1 and all plant characters just like local were evolved. The seed yield and oil content of these strains are as follows:-

TABLE No. 18

Yield and Oil Content of Strains H.C-5 to H.C-7 and Local

| Material | Seed yield | Oil content per cent on whole seed. |
|---|---|---|
| H. C-5 .. .. .. | 300 | 49 % |
| H. C-6 .. .. .. | 300 | 49 % |
| H. C-7 .. .. .. | 300 | 49 % |
| Local .. .. .. | 220 | 46 % |

Of these three strains, H. C-6 was preferred and this strain is now under multiplication and distribution.

Since these strains have plant characters just like the local, they cannot be differentiated from the local till spikes are put out. It was therefore felt that if the small-seeded character of H. C-6 could be combined with the other desirable characters of H. C-1, the combination will be an excellent strain. Hybridisation work was accordingly taken up between H. C-1 and some other lines with seed type like local, but with high oil content. As a result, the following cultures have now been evolved:-

TABLE No. 19

Yield and Oil Content of Hybrid Castor Cultures

| Material | Oil content per cent on whole seed. | Seed yield per acre. |
|---|---|---|
| 4560 | 56·75 | 320 lb. |
| 4561 | 54·60 | 320 ,, |
| 4564 | 53·71 | 320 ,, |
| 4567 | 51·16 | 320 ,, |
| 4569 | 53·77 | 320 ,, |
| 4570 | 53·00 | 320 ,, |
| 4571 | 55·35 | 320 ,, |
| Local | 46·00 | 220 ,, |

All the strains evolved at Himayatsagar Farm are mostly female, non-shattering, branching and with seed type either like local (11·19 x 7·79mm). or medium sized (13·54 x 9·80 mm.).

Besides evolving strains with desirable characters, work has also been done in establishing lines pure for:-

| | |
|---|---|
| *Stem colour:-* | i) Green stem, ii) Red stem. |
| *Blooms:-* | iii) No bloom iv) Single bloom, v) Double bloom, vi) Triple bloom. |
| *Spine on fruits:-* | vii) Spiny, viii) Non-spiny. |
| *Size of fruits:-* | ix) Larged-sized fruit, x) Medium-sized and xi) Small-sized. |
| *Colour of fruits:-* | xii) Green fruit colour, xiii) Pink fruit colour. |
| *Seed size:-* | xiv) From the smallest (7·95 x 5·30 mm.) to the largest (20·95 x 13·50 mm.) with all intermediates. |
| *Seed colour:-* | xv) Dark chocolate, (xvi) Pink, (xvii) White (xviii) Brown, (xix) Deep red. |
| *Spike types:-* | (xx) Mostly female, xxi) Partially female. |
| *Spike nature:-* | (xxii) Very loose spikes, (xxiii) Semi-compact, (xxiv) Compact spikes. |
| *Length of the pedicel bearing fruit:-* | (xxv) Very short approaching sessile, (xxvi) Long pedicel. |
| *Height of plant:-* | (xxvii) Dwarf—not exceeding 36 inches. (xxviii) Tall—going up to even 12 feet in height. |
| *Branching:-* | (xxix) Top branching—Commencing in the upper half region. |
| | (xxx) Basal branching—Commencing in the lower half region. |
| *Lines with high oil content:-* | (xxxi) These lines yield oil content anything more than 52 per cent on whole seed but not all other characters are desirable. |

*Shape of spike:-* (xxxii) Conical, (xxxiii) Cylindrical.

(*g*) *Castor varieties evolved by various States:-* Castor varieties are either annual or perennial. The latter are found growing wild in almost all districts. They are to be found growing in the backyards of houses and are found to be thriving at altitudes of 3,000 to 6,000 feet. The perennials are profusely branching and grow almost like trees. The perenial plants yield abundant seed, but cannot be raised as field crops and hence are not of economic importance. The oil of perennial types is of inferior type and hence was used mainly for illumination. In Brazil, it is the perennials that are planted along river sides and these plantations get river silt and water from periodical inundations. This results in good yields of castor, with the least cost in raising the same. It is not known if attempts have been made to improve the perennials both for yield and oil content, except in Madras, where a high-yielding perennial strain with high oil content has been isolated.

In India and other countries, it is the annual type of castor on which most of the crop improvement work has been done. As a result, a large number of castor strains superior to local varieties both in respect of seed yield and oil content have been evolved and these have been described in Table No. 20.

## TABLE No. 20

### Description of Improved Strains of Castor Evolved by Different States in India

| Name of State | Strain | Season | | Duration of crop | Seed colour | Seed size | Average acre yields in lbs. | Oil content per cent | Special features |
|---|---|---|---|---|---|---|---|---|---|
| | | Sowing | Harvesting | | | | | | |
| Madras .. | T.M.V-1 | May-June | Jan.-Feb. | 6½ months | Grey | — | 750 | 51 | Plants short, 4'-6', compact. Inflorescence 1½'-2', high yielding, short duration. |
| | T.M.V-2 | ,, ,, | ,, ,, | 6½ - 7 months | Red Brown | — | 775 | 50 | Plants medium height, capsules sparsely set, inflorescence 2'-3'. High yielding, medium duration. |
| ,, | T.M.V.-3 | ,, ,, | ,, ,, | 8 months | ,, | — | 750 | 55 | High-yielding, high oil content long duration irrigated variety, suited for borders. |
| Bombay.. .. | S-20 | 2nd week August | End of Feb. | 195 days | Grey | — | 875 | 44 | — — — |
| Mysore .. .. | L-53 | May - June | Dec. - Jan. | 6 to 8 months. | — | — | 250-300 | 47 | Drought-resistant |
| ,, | L-54 | | | | | | | | |
| | L-242 | | | | | | | | |
| ,, .. .. | L-73 | ,, ,, | Sept-.Oct. | 130-180 days. | — | — | 350 & above | 48 - 49 | Suitable as mixture and for medium rainfall. |
| | L-74 | | | | | | | | |
| ,, .. .. | L-77 | | | | | | | | |
| ,, .. .. | L-280 | ,, ,, | ,, ,, | ,, | Grey | — | 300 - 350 | 48 - 49 | Drought-resistant. |
| Uttar Pradesh .. | T-3 | ,, ,, | Dec.-Jan. | 6-8 months | — | Bold | 1000-1200 | — | Suitable for both *kharif* and *rabi* |
| Madhya Pradesh | E.B.-16 | ,, ,, | ,, ,, | ,, | — | ,, | 388 | 50·91 | — — — |
| ,, | E.B.-31 | ,, ,, | ,, ,, | ,, | — | ,, | 431 | 44·30 | — — — |
| ,, | E.B.-9 | Rabi variety | | | — | Small | 200 | 47·84 | — — — |
| Andhra Pradesh | H.C.-1 | July-Aug. | Mar.-April | 9 months | Dark with red tinge | Medium | 300 | 51 | Non-spiny. Has done well in other parts of India. |
| ,, | H.C.-2 | ,, ,, | ,, ,, | ,, | Reddish | Small | 350 | 49 | Spiny |
| ,, .. | H.C.-3 | ,, ,, | ,, ,, | ,, | Dark red | Medium | 350 | 49 | ,, |
| ,, .. | H.C.-4 | ,, ,, | ,, ,, | ,, | Dark chocolate | ,, | 350 | 49 | ,, |
| ,, .. | H.C.-5 | ,, ,, | ,, ,, | ,, | Dark brown | Small like local | 350 | 48 | ,, |
| ,, .. | H.C.-6 | ,, ,, | ,, ,, | ,, | ,, | ,, | 350 | 49 | ,, |
| ,, .. | H.C.-7 | ,, ,, | ,, ,, | ,, | ,, | Slightly bigger than local | 350 | 48 | ,, |

## CHAPTER X

# *CHEMISTRY AND TECHNOLOGY OF CASTOR OIL, CAKE AND STALKS

## I. Castor Oil

### 1) *Occurrence and General Characteristics*

Castor oil occurs to the extent of about 45 per cent in the bean, with a range of 35 to 51 per cent; there appears to be some tendency for greater oil content to be associated with larger seeds[55] so that cultivation of the latter would appear doubly advantageous.

The presence in castor oil of glycerides of the unsaturated hydroxy acid, ricinoleic acid, present to the extent of some 90 per cent, imparts to the oil certain distinctive properties : high acetyl or hydroxyl value, high specific gravity, refractive index and viscosity, low saponification value, miscibility with ethyl alcohol and near-insolubility in light petroleum ether. The usual limits for the analytical characteristics for castor oil are reflected in the following standards recommended by the American Oil Chemists' Society.[180]

**TABLE No. 21**

**Recommended Standards for Castor Oil of the American Oil Chemists' Society**

| | |
|---|---|
| Specific gravity at 25°/ 25°C | 0·945—0·965 |
| Refractive index at 25°C | 1·473—1·477 |
| Iodine value (Wijs) | 81—91 |
| Saponification value | 176—186 |
| Unsaponifiable matter, per cent | Not over 1·0 |
| Acetyl value (Andre-Cook) | Not less than 144 |

The range of analytical figures for 19 samples of castor oil from all over the world is shown by the results of Gupta, Hilditch and Riley [55]:-

| | Range | Average | Remarks |
|---|---|---|---|
| Refractive index at 25°C | 1·4768—1·4792 | 1·4779 | |
| Iodine value (Wijs) | 84·0 —85·8 | 84·9 | |
| Saponification value | 179·0 —182·7 | 180·5 | |
| Acetyl value | 145·0 —153·2 | 150·0 | One specimen 139·4 |
| Unsaponifiable matter, % | 0·5 —1·1 | 0·8 | „ 1·8 |
| Free fatty acids (per cent ricinoleic) | 0·4 —5·2 | 1·6 | „ 18·0 |

* Contributed by K. T. Achaya, M. A. Sivasamban and S. Neelakant Rao under the guidance of Dr. S. Husain Zaheer, Director, Regional Research Laboratory, Hyderabad (Dn).

The viscosity of various samples of castor oil lies between 935 and 1033 centipoises at 20°C. [76] A sample with a viscosity of 1,000 centipoises at 20°C had the following viscosities at other temperatures: 453, 232 and 128 centipoises respectively at 30°, 40° and 50°C. [43] The density of castor oil varies linearly from 0·972 at O°C to 0·870 at 154°C. [28] Castor oil is strongly dextrorotatory because of the asymmetric carbon atom in ricinoleic acid; the rotation in a 200 mm. tube is from + 7·6 to + 9·7, the range reflecting the content of ricinoleic acid.

Castor oil is miscible in all proportions with glacial acetic acid and absolute alcohol. At 15°C. it also dissolves in 2 volumes of 90 per cent ethanol and in 4 volumes of 84 per cent ethanol. The oil is nearly insoluble in large quantities of petroleum ether, kerosene and higher-boiling paraffin oils, as little as 0·5 per cent of castor oil causing a turbidity. Castor oil gives a homogeneous solution with an equal measure of light petroleum or with 1·5 volumes of kerosene or paraffin oil; any solvent in excess of this floats over the mixture as a separate layer. [86] This excess solvent carries with it a small proportion of soluble (mostly di-ricinoleo) glycerides, and by repeated extractions, almost pure triricinolein in about 75 per cent yield can be obtained[1]; this material has an even higher acetyl value (160-161) and viscosity than castor oil. The characteristic insolubility of castor oil in the solvents mentioned is lost if even a small quantity of another oil is present.

Castor oil has a strong laxative action, which has been shown to be due to the ricinoleo glycerides themselves and not to any adventitious compound, since purified ricinoleic acid and esters also show this property. The cathartic action is exerted on the intestinal mucosa or the Auerbach plexus, and is independent of the absorption of its constituents from the intestine. [159]

On keeping castor oil, little increase in acid value or decrease in acetyl value occurs, but specific gravity increases markedly probably owing to internal reactions among the ricinoleo glycerides with their reactive hydroxyl groups.

2) *Chemical Composition of Castor Oils*

The presence of ricinoleic acid in large amounts in castor oil was recognized by Saalmüller in 1848, and its constitution established by Goldsobel in 1894, while the occurrence of stearic, oleic, linoleic and dihydroxystearic acids in small amounts was shown qualitatively over the years. The precise estimation of these component fatty acids is rendered difficult with standard analytical procedures owing to interference by the hydroxy fatty acids and difficulties in the precise estimation of acetyl values. Table No. 22 shows

some more recent results using improved techniques, of which perhaps the more accurate are those of Sreenivasan, Kamath and Kane. [137] They determined the composition of castor oil by careful conversion to methyl esters, separation of hydroxy from non-hydroxy esters by reaction with succinic anhydride in toluene solution, and estimation of unsaturation by a bromometric procedure in preference to using a standard iodine value reagent, while dihydroxystearic acid was determined by oxidation with periodic acid and saturated acids by difference or actual isolation. The considerable differences in the Table are almost certainly due to the use of different analytical techniques.

**TABLE No. 22**

**Component Fatty Acids of Castor Oil, Per Cent by Weight**

| | Saturated | Oleic | Linoleic | Ricinoleic | Dihydroxy-stearic |
|---|---|---|---|---|---|
| | | Average figures | | | |
| Gupta *et al*[55] .. .. .. | 1·1* | 0·4 | 4·4 | 93·4 | 0·7 |
| Sreenivasan *et al*[137] .. .. | 3·4 | 5·4 | 3·5 | 85·7 | 2·0 |
| | | Range of figures | | | |
| Gupta *et al* (19 samples) | Nil-2·5 | Nil-6·8 | 3·9 - 5·0 | 85·9 - 94·8 | 0·5 - 1·0 |
| Sreenivasan *et al* (3 samples) .. .. .. | 3·0 - 3·5 | 5·1 - 5·8 | 3·4 - 3·5 | 85·5 - 86·0 | 1·6 - 2·4 |

* *A pooled sample of saturated acids analysed to myristic 3, palmitic 35, stearic 57 and arachidic 5, as percentages by weight.*

The glyceride composition of castor oil, *i.e.*, the actual assembly of the different fatty acids in the glyceride molecules as triglycerides, is even less definite than the component fatty acids. Only one glyceride analysis has been reported,[55] and is subject to the same limitations of analytical technique.

**TABLE No. 23**

**Component Glycerides of Castor Oil (% mol.)[55]**

Analytical characteristics of castor oil:-I. V. 84·5, S. E.=309·4, Acetyl value 149·3, component fatty acids (per cent by wt.):-Satd. 2·3, oleic 0·1, linoleic 4·7, ricinoleic 92·2, dihydroxystearic 0·7.

| | |
|---|---|
| Saturated-diricinoleins | 7·3 |
| Oleo „ | 2·5 |
| Linoleo „ | 13·4 |
| Dihydroxystearo „ | 2·0 |
| Triricinolein | 74·8 |

No evidence was found for the presence of any monoricinoleo-glycerides.

### 3) *Extraction and Refining of Castor Oil*

The common systems of oil expression or extraction are applicable to castor oil, with certain limitations owing to the nature of the material. Since the seed contains toxic materials (see below), castor oils are not usually processed in equipment in which other oilseeds are to be worked. The presence of allergenic materials necessitates precautions against inhalation of dust, while the cooking of seed with moisture, often used to better yields with other oilseeds, activates the enzymes present and causes sludge formation, and is not used.

The finest quality of almost colourless castor oil for medicinal and aero-engine lubrication purposes is produced by crushing in the cold the kernels obtained by decortication. Shelling is done between rollers so adjusted according to seed size that only the outer shell is broken; the shells are subsequently blown away. The once-expressed cake may be pressed again hot, or solvent-extracted with heptane, benzene or trichlorethylene to give inferior grades of oil. In the U. S. A., hydraulic pressing of the cleaned whole seed in cage-presses at 40-80°C appears to be the common practice, followed by solvent extraction of the cake containing 10-20 per cent oil. In other countries, *e.g.* Brazil, which is an important producer of castor oil, continuous screw-presses are largely used for oil expression. The cooking of crushed seed with live steam, occasionally practised in India, yields a large quantity of sludge and involves considerable oil losses, besides the provision of special equipment for filtering or centrifuging. Bleaching with activated earths or even by exposure to sunlight in thin layers in enamelled or white-tiled pans and coagulating the albumen by heat or steam, followed by filtering, gives a pale-coloured oil. The British Standard for castor oil of "Firsts" quality specifies a maximum colour of 2·2 Y, 0·3 R on the Lovibond scale in a 1-inch cell.

Alkali-refining of castor oil is difficult owing to the tendency of neutral oil to saponify easily and the great emulsifying power of castor soaps for oil; it is not often necessary since the oils rarely attain a high free acidity in the seed, or even after expression and storage. Moreover, very low free acidity is striven for mainly in edible oils.

### 4) *Uses and Transformations of Castor Oil*

The principal uses of castor oil in America are for the production of dehydrated castor oil for use in the surface coating industry, the manufacture of plasticisers like blown oil and esters of ricinoleic acid, and the production of sebacic acid. Naturally the outlets for the oil are widely different in India,

where the traditional uses, such as for catharsis, lubrication or fat-liquoring of leather, would still be prominent for such oil as is retained in the country even after the very considerable exports (some 80 per cent of production). The various applications of castor oil may now be considered.

a) *Soaps*

The sodium soap of castor oil, sold as technical sodium ricinoleate and containing about 85 per cent of the material, requires considerable quantities of salt for "salting out". It is however not used on a large scale even though it is a very hard, richly-lathering material. Since it imparts transparency, it has some special use in the manufacture of transparent soaps. Sodium ricinoleate is known to have a strong bactericidal action, as also the sulpho-ricinoleate, and both are used in toothpaste formulations for this reason, despite a somewhat unpleasant bitter taste.

b) *Lubricants*

Castor oil is widely used in India as a solid contact lubricant in railway engine and locomotive bearings; though too thick in colder climates for this purpose, it finds use in lubricating marine engines. Blended oils, a mixture of fatty oils, liquid waxes and mineral oils, are largely used for internal liquid lubrication of steam cylinders, as in railway engines, where the relative non-volatility of the fatty oil makes for economy. Castor oil is unusually resistant to oxidation, and ideally suited for this purpose; since it does not mix with mineral oil, it is rendered soluble by heat treatment, blowing with air or mixing with another fatty oil like rape oil, tallow or lard. Blends of refined castor oil with groundnut or rape oil stabilised with an antioxidant have been used as lubricants for internal combustion engines like motor engines under emergency conditions.[2]

High cost was one reason for the gradual replacement of castor oil by cheaper mineral oils over the last fifty years as lubricants for petrol engines. In recent years, castor oil has again gained importance in the lubrication field not as such but as a source of sebacic acid, the esters of which, by virtue of maintaining their viscosity over a very wide temperature range, have become almost indispensable components of the lubricants used in high-speed aeroplane engines. Hydraulic brake fluids contain substantial proportions of castor oil in solution in ethanol.

c) *Surface Coatings*

Empirical statements indicate that heated castor oil has long been known as a drying oil, but the nature of the change undergone in the heating process

was not understood. The discovery by Scheiber [128] that the elements of water can be removed from ricinoleic acid by heat to give a product containing conjugated dienoic (isomeric linoleic) acids was soon put on a commercial basis using whole castor oil.[149] A vast variety of catalysts for the dehydration have been patented, including sulphuric acid and alkali bisulphates, sulphonic acids and salts, activated acid earths, tungstic acids, etc. The dehydration can give rise to either a non-conjugated or a conjugated dienoic product.

$$CH_3\ (CH_2)_4\ \underset{H}{CH}\text{-}\underset{OH}{CH}\text{-}\underset{H}{CH}\text{-}CH=CH(CH_2)_7\ COOH \quad \text{Ricinoleic acid}$$

$$\Big\downarrow \text{ dehydration}$$

$$CH_3\ (CH_2)_4\ CH=CH\text{-}CH_2\text{-}CH=CH(CH_2)_7\ COOH \quad \text{Non-conjugated acid}$$

or

$$CH_3\ (CH_2)_4\ CH_2CH=CH\text{-}CH=CH(CH_2)_7\ COOH \quad \text{Conjugated acid}$$

The presence of the conjugated acid imparts to dehydrated castor oil, or DCO for short, the property of forming a solid film on exposure to air, *i.e.* the property of functioning as a 'drying' oil for use in paints and surface coatings. Contrary to the earlier claims of Scheiber, later work [106] has shown:

i) that the dehydration is never complete but proceeds only to the extent of about 80-85 per cent, and that hydroxy acids always remain to the extent of 3-8 per cent;

ii) that the proportion of conjugated acids is much less than that of non-conjugated, the usual figures being about 20 per cent and 60 per cent respectively.

Also, it is now known that common analytical methods, *e. g.* acetyl value determinations, do not reveal the true state of affairs owing to the presence of protected hydroxyl groups (formed by ester-interchange between glycerides and the hydroxyl groups of the ricinoleic radical), partially-hydrolysed glycerides, estolides, etc.[74]

A typical dehydration is carried out at a temperature of 220-240°C at a pressure of 4-6 mm. of mercury (to facilitate removal of the abstracted water and prevent oxidation) using 2 per cent of sodium bisulphate as catalyst and 0·4 per cent of sodium bisulphite as promoter [133]; quick cooling and neutralisation with slaked lime was necessary to produce a light colour in the

final product, a matter of some importance since DCO is particularly useful for white finishes. Nearly instantaneous dehydration, with production of DCO of very high unsaturation (Woburn iodine value of 175 against 150 for ordinary DCO) is produced using organic sulphonic acids as catalysts, though the molecular weights are double that of ordinary DCO. [82] A major drying defect of ordinary DCO is the presence of an objectionable after-tack even on complete drying; this has been attributed to various causes, but is said to be overcome by using DCO of low viscosity, which is substantially unpolymerised or monomeric [163]; a product of viscosity 1·4 poises (at 25°C) could be produced in the sodium bisulphate process described above by arresting the polymerisation using a special agent. [132] Most DCO samples are marketed after bodying, *i. e.*, heat-thickening, which can be satisfactorily accomplished under vacuum [133]; Indian Standard Specifications are laid down only for bodied DCO and are as follows: viscosity at 30°C. 15-25 poises, acid number 8-16, saponification number 190-200, I. V. (Wijs, 1 hour) 90-112, colour (Lovibond, 1 cm. cell) 4·4 Y+0·4 R (calculated), set-to-touch time (with 0·05 per cent cobalt as drier) not more that four hours, sp. gr. 30°/30°C 0·944 - 0·951.

The particular virtues of DCO in surface coatings are its light colour and non-yellowing nature, coupled with its flexibility, which makes it particularly valuable in white surface finishes, *e. g.* for refrigerators. Generally its properties are intermediate between those of tung oil, which is more highly conjugated and therefore faster drying, and those of linseed oil, which contains linolenic acid and therefore has strong after-yellowing tendencies, besides being slower drying, and with poorer resistance to water and alkali, than DCO. In its behaviour with pigments, DCO shows good wetting properties and resistance to livering. These various qualities enable DCO to be used in a wide variety of surface coatings. Various viscosity grades are used in the manufacture of paints and enamels. In combination with tung and perilla oils and with limed rosin and phenolic resins, good vehicles for high-gloss and eggshell whites are obtained.[44] High quality varnishes, and white enamels of high gloss for air-drying and baking purposes with maleic type resins, can be made. DCO and its distilled fatty acids are becoming increasingly popular in the manufacture of alkyd resins; particularly, the use of monomeric DCO (see above) enables alkyds of high viscosity and low acid value to be manufactured [87] which are free from the only major defect of DCO, the presence of an after-tack on drying. It is also used in products like overprint varnishes, alkali-proof vehicles and synthetic lithographic varnishes in the printing ink industry, [53] besides being employed for linoleum and oilcloth manufacture.

d) *Wetting Agents and Detergents*

In recent years the sulphonation or sulphation of various fatty materials with some form of sulphuric acid (concentrated acid, oleum, fuming sulphuric acid, chlorosulphonic acid, etc.) to give materials whose sodium salts have valuable wetting or detergent properties has been widely developed, especially for textile use. As far back as eighty years ago castor oil was being similarly treated with sulphuric acid and partially neutralised to give a material called Turkey Red oil, a mixture of sulphonated alkali salt and unaltered castor oil, which was widely used in cotton dyeing or printing with alizarine dyestuffs such as Turkey Red; it brightened and added lustre to the dyed fabric by a combination of wetting, emulsifying and mordant action. The sulphonation occurs mainly at the hydroxyl group, but may also affect the double bond and cause various other side-effects like hydrolysis, polymerisation, estolide or inner ester formation, etc. It is usually carried out on a large scale at ordinary temperature (without allowing this to go too high) using concentrated sulphuric acid, removing the unspent acid by dilution and washing with brine and water, and partially neutralising with soda till the material is completely miscible with cold water. It can also be fully neutralised to give textile soaps.

The failure of ordinary soaps to lather in hard water due to precipitation of calcium and magnesium soaps, and in acid water by reason of precipitation of insoluble fatty acids, gave rise to improved detergent products. One of the first of these were the Monopole soaps, introduced about 1900 in Germany, [141] in which the sulphonation of castor oil was combined at some stage with heating to encourage the formation of inner esters or estolides. In the original patent of Stockhausen, castor oil is treated with 30 per cent of concentrated sulphuric acid and neutralised in the hot with caustic soda, while in other patented methods [118,12] castor oil fatty acids are either heated and then sulphonated or vice-versa. The Monopole soaps are clear honey-coloured viscous materials extremely stable to lime salts, magnesium salts and dilute acids and used for their surface-active properties in several stages of textile operations like desizing, bleaching, dyeing, printing, etc.

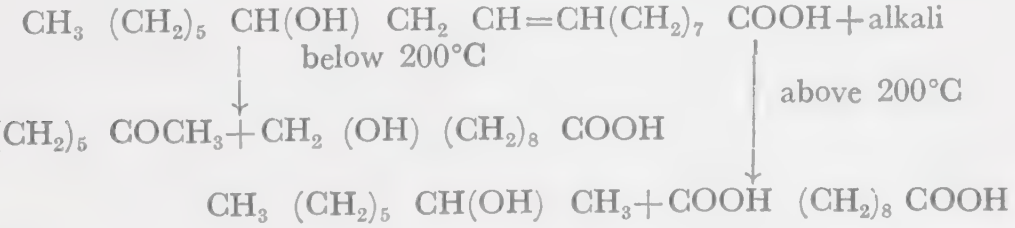
The lower esters of ricinoleic acid like the butyl, amyl and propyl esters, which are usually prepared by trans-esterification *i. e.* heating together castor oil with the corresponding lower fatty alcohol in the presence of about 2 per cent sulphuric acid as condensing agent, yield on sulphation and neutralisation products having greater foaming and wetting power than neutral sulphated castor oils. [119] Owing to their high rewetting power and lubri-

cant action on textile fibres the former are widely used in the industry under such names as Avirol AHX, Surfax WO and Parapon.

Yet other surfactants are obtained by sulphating the monoglycerides derived from castor oil by heating with two molecular proportions of glycerol in the presence of a catalyst like boric acid, quinoline, pyridine, etc., and purifying the resultant mixture containing mono-, di- and triglycerides by molecular distillation. The properties of the sodium salts are similar to the sulphated esters, *i.e.*, wetting rather than highly detergent. [134] It may be added here that the monoglycerides from vegetable oils are produced on a large scale for their emulsifying properties which find them use in various fields, *e.g.* baking.

e) *Production of Sebacic Acid and Secondary Octyl Alcohol*

Heating the sodium salt of castor oil, *i.e.* of ricinoleic acid, in the presence of excess alkali gives rise to different main products depending on the temperature. Below 200°C, the products are methyl ethyl ketone and *omega*-hydroxy-decanoic acid, while above this temperature secondary octyl alcohol and sebacic acid are produced. [58]


CH3 (CH2)5 CH(OH) CH2 CH=CH(CH2)7 COOH+alkali
below 200°C
above 200°C
CH3 (CH2)5 COCH3+CH2 (OH) (CH2)8 COOH
CH3 (CH2)5 CH(OH) CH3+COOH (CH2)8 COOH

The latter process is worked commercially in the U. S. A and Britain, but not so far in India. In a typical experiment, [151] castor oil soap containing 20 per cent moisture was heated for 8 hours at 260°C in the presence of 30 per cent excess sodium hydroxide under a steam pressure of 70 lb. per sq. inch. The octyl alcohol was steam distilled for 50-70 hours at 200°C and then fractionally distilled (yield of alcohol, 30 per cent), and the residue acidified and filtered to yield the sebacic acid (yield, 53 per cent). The yield of alcohol could be improved to 37 per cent using sodium carbonate as the excess alkali. Numerous variations have been described : Lane[83] mills the castor oil and alkali into a friable mass, places it in an autoclave, evacuates air rapidly and directs steam at 325°C for 4 hours against the mass to get yields of 72 per cent alcohol and 74 per cent acid. According to a paper based on commercial operation, [71] the success of the process depends on overcoming such difficulties as keeping the foaming mass homogeneous, uneven heating

and corrosive nature of the alkali material; good results are claimed by the use of concentrated aqueous solutions under high temperatures and pressures and of ricinoleyl alcohol rather than castor oil as starting material, slow controlled addition of alkali to minimise foaming, and the carrying out of the process in two stages to first give *omega*-hydroxydecanoic acid.

Sebacic acid is a white powder soluble only very slightly in water but easily in alcohols, ketones and esters. It combines with monohydric alcohols to give esters which are highly efficient plasticising agents, *e. g.* dimethylglycolsebacate, dibutylsebacate, dioctylsebacate, whose physical properties like viscosity and elasticity are only slightly affected by temperature changes, in addition to possessing good water resistance, flexibility and stability. Owing to the presence of two remote carboxyl groups, sebacic acid provides polyfunctionality in surface coatings like synthetic resins (alkyds or polyesters), synthetic rubbers and synthetic fibres of the polyamide type.

Secondary octyl alcohol (b. pt., 180°C.) is used for the production of plasticisers like its adipate and phthalate salts, as an anti-foam agent, in lacquers, and as a solvent in place of butanol for urea-formaldehyde and polyvinylchloride resins.

f) *Pyrolytic Decomposition to Undecylenic Acid and Heptaldehyde*

While the heating of castor oil at about 220°C. leads to dehydration as described earlier, at temperatures of 450°C. pyrolytic decomposition occurs to give mainly heptaldehyde and undecylenic acid.

$$CH_3\ (CH_2)_5\ CH(OH)\ CH_2CH{=}CH(CH_2)_7\ COOH \xrightarrow{450^\circ C.} CH_3(CH_2)_5\ CHO + CH_2{=}CH(CH_2)_8\ COOH$$

The pyrolysis is usually conducted under vacuum with careful heating, and the mixture of the two products that distils over is fractionally distilled again to give the components, generally in yields of about 20 per cent each on the weight of oil. The spongy mass left behind appears to be mainly polymerised undecylenic acid, from which further yields of the latter may be obtained by saponification with alcoholic alkali, acidification and distillation; it may also be used for preparing varnishes, oilcloth and insulating tape [143]. Increased yields using continuous processes are obtained by passing the oil through variously-filled heated metal or silica tubes, [67,68] or by impinging the oil against a hot molten metal surface. [136] The

process is not worked commercially in India, and perhaps only to a limited extent elsewhere.

Heptaldehyde is itself used as a perfume, and in the manufacture of heptyl heptoate, a perfume which combines well with coumarins. Its most important use is in the production of methyl heptine, usually used as the carbonate in extremely dilute ethanol solution in the preparation of violet, ionone and lilac perfumes ; dichloroheptane is treated with sodamide, ethanol or dry caustic soda, and carbon dioxide bubbled through the product.

Undecylenic acid is also used in perfumery : the alcohol has an intense, penetrating odour, and the saturated aldehyde, undecanaldehyde, is used in the modification of floral odours. From undecylenic acid can also be obtained large-ringed ketones of 10-12 carbon atoms resembling jasmine in scent. Undecylenic acid finds wide use as a bactericide and fungicide, being incorporated into proprietary medicines for the treatment of fungus skin diseases like athletes' foot.

*g) Hydrogenation*

About 1950, commercial samples of almost completely hydrogenated castor oil appeared on the market ; these had melting points of about 85°C., and were stated to be extremely useful in lithium-based lubricating greases, in polishes and plastics and as a shellac blend. To obtain high-melting products, it is necessary to retain the hydroxyl group intact while saturating the double bond. This is favoured by the use of low temperatures (100 to 150°C) and high pressures (200 lb. per sq. in.) for 14 hours under ordinary hydrogenation conditions using commercial nickel catalyst, while high temperatures (250°C) and low pressures (70-75 lb./sq. in.) for long periods (38 hours) yield stearic glycerides of lower melting points.[54]

*h) Miscellaneous*

Early patents, now mostly obsolete, describe the transformation of castor oil by various empirical means into plastic or brittle masses, which could be used as rubber substitutes, varnish and lacquer ingredients, plasticisers, etc. The cracking of castor oil or whole castor seed under pressure yields motor and diesel fuels.[91] Ricinoleic acid finds use as an ingredient in chemical contraceptives where it functions by so lowering the surface tension that the sperms are disrupted. Amides from castor oil are vaseline-like materials which yield on pyrolysis (analogous to the oil) undecylamides used in fly sprays and insecticides. [42]

## II. Castor Cake

The cake remaining after crushing or extracting castor seeds for oil is known as *poonac* or pomace. The oil content of the cake can usually be reduced quite low, 6 to 6·5 per cent, by efficient crushing, while solvent extraction, of course, brings it down to below two per cent. Typical compositions of decorticated and undecorticated cake are shown in Table 24.

**TABLE No. 24**

**Percentage Composition by Weight of Castor Cake (pomace)**

| | Decorticated | Undecorticated |
|---|---|---|
| Oil .. .. .. .. .. | 8 | 6·5 |
| Proteins .. .. .. .. .. | 46 | 20·5 |
| Carbohydrate and fibre .. .. .. .. | 26 | 49 |
| Moisture .. .. .. .. .. | 9·5 | 9 |
| Minerals .. .. .. .. .. | 10·5 | 15 |

Castor seed, and hence castor cake, contains at least three toxic materials [78]; first and most important, a protein, ricin; secondly, a very powerful allergenic material, active in concentrations of even 1 in $10^6$, which is a protein-polysaccharide of low molecular weight, chemically and immunologically distinct from ricin; and thirdly, a mildly toxic alkaloid, ricinine. Any method which removes or inactivates the protein, such as heat treatment, which causes protein denaturation, or sodium chloride treatment, which causes its precipitation, will destroy most of the toxicity, but these are not employed on any large scale, even though a cake of excellent feeding value would result. It would also be necessary to use decorticated castor cake, as otherwise the jagged shell pieces damage the intestines of cattle. Today the cake is used entirely for manurial purposes, being rich in nitrogen; it is also a good source of minerals, being rich in ash (6-9%) which contains 25% $P_2O_5$, 17% CaO, 14% $K_2O$, 10% MgO, 6% $Fe_2O_3$, etc.

The proteins from castor seed have been isolated and used to produce distempers, oil-bound water paints, adhesives for wood and products similar to casein plastics [72].

Castor seed contains a lipase capable of hydrolysing glycerides and esters. This is the most active of several enzymes present (an amylase, invertase, maltase and endotrypsin). High purification of the enzyme lowers its stability; a mixed enzyme preparation, obtained as a fluffy

powder by decorticating castor seeds, thoroughly extracting the fat and then milling, keeps its activity even for years. [88] The enzyme method was actually used for commercial hydrolysis of fat especially in Germany, in spite of troublesome emulsion formation. The active enzyme is rapidly inactivated in an acid medium in the absence of fats, but in their presence is more stable. It is active only within a very narrow pH range, 4·7-4·8. [57] On the basis of the number of molecules hydrolysed, the enzyme shows no difference in rates of specificity for different oils. [88] Various Indian castor seed varieties have recently been used to obtain active enzyme preparations, the best of which hydrolysed 89 per cent of an oil within 24 hours. [98] Hydrolysis of unsaturated oils showed selective liberation of the more unsaturated acids especially in the early stages; at the 50 per cent stage of hydrolysis, the I.V. of the free fatty acids and of the unsplit residue were 119·7 and 75·0 for groundnut oil, 171·8 and 121·0 for safflower oil, and 203·2 and 135·0 for linseed oil respectively. [98]

## III. Castor Stalks

Castor stem pulp is believed to be used for the manufacture of paper; in India, laboratory and pilot-plant trials have shown that it can be used for production of writing, printing and wrapping papers. The use of 4 per cent alkali for digestion at 80 lb. per sq. inch gave a 40 per cent yield of bleached pulp leaving 30 per cent resistant fibre, [9] while other work gave a 57 per cent yield of pulp from unbarked castor stalks by the sulphate process. [8] The beaten pulp is short-fibred (average length 0·91 mm., average diameter 0·021 mm.) but mixed with about one-third of bamboo pulp has been used to obtain writing, printing and wrapping papers of good formation and satisfactory strength, [8] and like mechanical wood pulp which is also short-fibred, may be used alone to produce newsprint where strength is not of primary importance. [9]

## CHAPTER XI

# MARKETING, PROCESSING AND USES OF CASTOR

## I. Marketing

### (1) *Trade Description*

Report of the marketing of castor seed in India by the Marketing Department, Government of India, states that the trade recognises nine different qualities of castor and these are described below :—

(*a*) *Chitto :*—Small-seeded. Low oil content. Grown in Warangal district of Andhra Pradesh and some parts of Madras and Madhya Pradesh. This quality accounts for eight per cent of the produce coming to the market. Sells at a heavy discount. Mixtures of 'chitto' and "Hyderabad" in the proportion of 1 : 3 despatched from Warangal area to Bombay are known in trade as "Bombay chalan." The average oil content is 44·3 by press extraction and moisture per cent 5·4.

*N.B.:*—Difference between oil percentage determined by chemical process and by expellers, press etc., is usually 4 per cent. Thus when a breeder describes his variety to yield 50 per cent oil it means that by chemical extraction 50 per cent and by crude extraction *i.e.*, by expellers etc., 46 per cent.

(*b*) *Kathiawar :*—Small-seeded. Low oil content. Grown in the areas covered by the former Kathiawar States, including Junagadh, Jamnagar, Kutch etc., and parts of former Baroda State. Its share to total production is 6 per cent.

(*c*) *Madras :*—Medium-sized seed similar to "Hyderabad," but oil content lower than "Hyderabad." Grown in Anantapur, Bellary, Kurnool, Cuddapah, Guntur, and Nellore districts of present Andhra Pradesh and some parts of Mysore State. Its share to total production is 10 per cent. Sells at a discount as compared to "Hyderabad." In export trade both "Madras" and "Hyderabad" are shipped as "Bombay."

(*d*) *Hyderabad :*—Medium-sized seed with high oil content. It is grown extensively in Telangana of Andhra Pradesh and adjoining tracts in Madhya Pradesh. Its share to total production is 25 per cent. It is known as "Factory Chalan" in Hyderabad markets and "Mogalai" in Bombay

markets. Its oil content by crude extraction is 43 per cent and by chemical extraction 47 per cent.

(*e*) *Gujarat* :—Medium-sized seed. Oil content lower than "Hyderabad". Grown in Gujarat and Baroda areas of Bombay State. Its share to total production is 12 per cent. Sells at a lower price than "Hyderabad".

(*f*) *Calcutta* :—Bold seed. High oil content. Grown in Bihar. Its share to total production is 15 per cent.

(*g*) *Salem* :—Bold, deep-coloured seeds, medium oil content. Grown in Salem, North Arcot, South Arcot, Trichinopoly and Coimbatore districts of Madras State and some parts of Mysore State. Its share to total production is 7 per cent. This is supposed to yield oil with lower percentage of free fatty acids.

(*h*) *Cawnpore* :—Bold seed. Oil content varying. Grown in Uttar Pradesh and certain parts of Bombay State. Its share to total production is 14 per cent. This quality in trade usually consists of mixtures for seed size and oil content.

(*i*) *Pares* :—Bold seed. High oil content. Raised in parts of Andhra Pradesh, Madras and Bombay States. Its share to total production is 3 per cent. This quality is of minor importance.

(2) *Quantities Retained by Producers*

Taking the country as a whole, the quantities of castor seed retained by producers are estimated at 6 per cent of the total production.

(3) *Seasons of Marketing*

The peak period for marketing of this crop generally extends from February to April in Southern India and April to June in Northern India.

(4) *Imports*

There are no imports into India. About 1,000 tons of castor seed come from Nepal to Bihar markets.

(5) *Exports*

The general trend of imports and exports for various countries in the world is shown in Table No. 25.

TABLE No. 25.

Trade in Castor Beans

| *Exporting countries.* | Seed (Oil equivalent) '000 metric tons | | Oil '000 metric tons | |
|---|---|---|---|---|
| | 1954 | 1955 | 1954 | 1955 |
| Haiti .. .. .. .. .. .. | 0·8 | N.A | 1·0 | N.A |
| U.S.A. .. .. .. .. .. .. | N.A | N.A | 0·2 | 0·2 |
| Brazil .. .. .. .. .. .. | 27·0 | 17·0 | 15·7 | 21·0 |
| Ecuador .. .. .. .. .. .. | 3·0 | N.A | 2·2 | N.A |
| Paraguay .. .. .. .. .. .. | N.A | N.A | 0·4 | N.A |
| Thailand .. .. .. .. .. .. | 6·5 | N.A | N.A | N.A |
| China .. .. .. .. .. .. | 10·0 | 10·0 | N.A | N.A |
| India .. .. .. .. .. .. | N.A | N.A | 23·0 | 42·9 |
| Others .. .. .. .. .. .. | 22·7 | 20·0 | 2·5 | 1·0 |
| Total World .. .. .. .. .. .. | 70·0 | 55·0 | 45·0 | 65·0 |
| *Importing Countries.* | | | | |
| U. S. A. .. .. .. .. .. .. | 22·3 | 17·9 | 25·6 | 43·2 |
| Japan .. .. .. .. .. .. | 8·8 | 9·9 | N.A | N.A |
| United Kingdom .. .. .. .. .. .. | 9·6 | 4·1 | 10·0 | 15·9 |
| Western Germany .. .. .. .. .. | 7·6 | 7·6 | 1·8 | 1·3 |
| France .. .. .. .. .. .. | 8·0 | 10·3 | 1·5 | 1·3 |
| Others .. .. .. .. .. .. | 4·7 | 5·2 | 6·1 | 3·3 |
| Total World .. .. .. .. .. .. | 62·0 | 55·0 | 45·0 | 65·0 |

*N.B* :—Seed imports and exports are expressed in terms of oil equivalent at 45 per cent extraction rate. (N.A = Not available)

### (6) *Port of Shipment*

Formerly bulk of exports was from Bombay and only a minor portion was from Kathiawar ports. But recently exports from Kakinada and Madras have increased, with a decrease from Bombay.

## II. Processing

### (1) *Grading and Classification*

The producer does not grade or even clean the seed while taking the produce to the market. The seed is usually cleaned in mills, assembling markets and at ports where clearing charges are much higher than in villages.

(2) *Extraction*

Castor seed is crushed by power-driven mills, by bullock-driven *chekkus* and manually-operated screw presses.

(*i*) *Expellers :*—The seed is fed in the form of meal. An expeller crushes three to four tons of castor seed per day of 10 hours. Cost of crushing in 1943-44 (when prices were high) was Rs. 2-8-0 to Rs. 3-0-0 per maund of 82.5 lb.

(*ii*) *Hydraulic Presses :* —The seed is rolled into meal, heated and moistened by steam and pressed between plates by pressure from hydraulic pumps. Ten to twelve tons of seed is crushed in a day of 10 hours, costing the same as in the expellers.

(*iii*) *Rotary Mills :*—These are mostly in vogue in Gujarat and Baroda parts of Bombay State. About half a ton of seed is crushed in 10 hours, worked by a pair of bullocks.

(*iv*) *Chekkus :—Chekku* is the name in South India and *ghani* in North India. It is the indigenous oil-crushing device in India. It essentially consists of a pestle rotating in a mortar and is used for crushing various oilseeds all over India. The recovery of oil is much lower than from expeller. Quantity crushed per 10 hours is 80 to 125 lb.

(*v*) *Screw Presses :*—A screw-press, also called a hand-press, consists of a number of plates worked by a screw. The seed is turned into meal and packed into small packets of gunny bag cloth and placed in between two plates. A wheel is attached to the screw. This wheel is turned by 5 or 6 men and thus pressure is brought on the plates. Open heat is applied on either side of the press. The oil is squeezed and is collected in a trough below. About half a ton of seed is crushed in 10 hours by one screw. On an average, it costs about Rs. 2-12-0 to crush one maund (82·5 lb.) of seed. These presses were once very common both at Jadcherla and Bhongir, the largest castor markets in Telangana of Andhra Pradesh.

(*vi*) *Boiling Process :*—This process is practised by producers. Seed is crushed into meal, which then is boiled in water. The oil comes at the top. It is decanted and heated slightly to remove traces of moisture.

(3) *Yield of Oil and Cake*

Experiment conducted with oil extraction tests showed that even by screw process 42 to 43 per cent oil could be extracted, (the total being 46

per cent). The weight of cake varies from 58 to 65 per cent depending upon the moisture retained.

(4) *Crushing Seed With or Without Decorticating the Seed*

In Telangana of Andhra Pradesh the seed is crushed without decorticating. The entire castor produce that comes to Jadcherla and Bhongir markets is undecorticated seed. The analysis of the two types of cake is as follows :—

| | N | $K_2O$ | $P_2O_5$ |
|---|---|---|---|
| Cake from decorticated seed .. | 6·6% | 1·2% | 2·6% |
| Cake from undecorticated seed .. | 4·5% | 0·7% | 1·9% |

(5) *Agencies Engaged in the Marketing of Castor*

The proportion of marketable surplus taken by producers to the market varies from 10 to 75 per cent. It is estimated that in Bihar, only 10 per cent is taken to the market by the producers while in Uttar Pradesh, 50 per cent is taken. In Andhra Pradesh, 25 to 75 per cent produce is taken by producers directly to the market. For the whole of India, it may be said that about 50 per cent is taken to the market by producers and the remaining 50 per cent reaches the market through various types of middlemen. In some States, the prices offered by middlemen in the villages are better than the ones prevailing in the large markets.

## III. Uses of Castor

(1) *Castor Oil*

Castor oil is unique in its chemical composition. It remains viscous at high temperatures and liquid at low temperatures. It is a non-drying oil. On account of this, it is considered as one of the best lubricants and is extensively used in the manufacture of lubricants. Before 1914-1918, railways used to buy large quantities of castor oil for lubrication. Some of the railways had their own mills. During the last two decades, castor oil has been replaced to a large extent by mineral oil.

Castor oil is also used in various industries such as textiles, flour milling, as lubricant. Its medicinal use is known since a long time. Castor oil is used for lighting purposes in rural areas and some of the railways use it for lighting the signal and hand lamps. Castor oil and kerosene are mixed in the proportion of 7 : 1.

It is estimated that about 5,000 tons of castor oil are annually utilised in the preparation of sulphonated castor oil, known as Turkey oil which is used in cotton dyeing, printing and leather industries.

About 3,000 tons of castor oil are consumed in the manufacture of soaps. Castor oil imparts a certain degree of transparency to soaps. Castor oil soaps impart a shining and silky appearance to jute fabrics.

Raw castor oil is used for promoting growth of hair. Castor oil is used in the manufacture of refined and perfumed hair oil. It is estimated that about 2,000 tons of castor oil are utilised for this purpose.

Dehydrated castor oil is the largest new development for conversion to Sebacic acid, an important ingredient for the synthesis of Nylon fibre.

Castor oil or its derivatives are used in the manufacture of disinfectants such as phenyles. About 1,000 tons of castor oil are consumed in this industry.

The use of castor oil as a purgative is well known. About 2,000 tons of oil are consumed for medicinal purposes. In rural areas, castor oil obtained by boiling the seed, is considered better. In medicinal uses, castor oil has to satisfy the British Pharmacoepia Standard as shown below :

| | |
|---|---|
| Specific gravity at 15·5° C | 0·958 to 0·969 |
| Saponification value | 177 to 187 |
| Refractive index at 40° C | 1·4695 to 1·4730 |
| Acid value | Not more than 4 |
| Iodine value | 82 to 90 |

The oil for medicinal purposes is required to remain bright when cooled to 0°C and kept at that temperature for 3 hours. Its optical refraction should not be less than three to five.

(2) *Castor Cake*

There have been no imports of castor cake. Before 1914-1918, United Kingdom and some other countries took some castor cake from India, but in recent years, the exports to other destinations have been negligible. But Ceylon is the only buyer outside India.

No correct statistics about production and movement of castor cake are available as, in the yearly statistics issued either by Government of India or State Governments all oilcakes are put under one category. As already

stated, India produces about 1,50,000 tons of castor seed. If the entire seed were crushed in India, the total production of castor cake would not exceed 80,000 tons. The marketing report of Government of India estimates the production of cake in India at 95,000 tons even after exporting large quantities of seed. The Indian oilseeds statistics as compiled by the Directorate of Economics and Statistics, Government of India, 1950, estimated that during the period 1936-37 to 1948-49, the lowest production of castor cake in India was 17,000 tons in 1940-41 while the highest production was 67,000 tons in 1942-43.

The entire quantity of castor cake available is used as manure as it contains 4·5 per cent of nitrogen. Castor cake is mostly used for sugarcane fields as this cake is not attacked by white ants.

CHAPTER XII

# DISEASES OF CASTOR

By

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Although castor plant (*Ricinus communis* L.) serves as an important source of raw material for many industries and is reported to suffer severe losses due to many diseases caused by fungi and bacteria, yet not much work on the disease aspect has been done in this country. Some of the diseases which are considered important are discussed here.

## Seedling Blight

The disease is known to exist in India since 1909 when it was first reported from Pusa, Bihar (Dastur, 1913). It generally appears during rainy season, *i.e.*, about the end of June and continues upto September. The disease is severe in low lying and badly drained fields and it is in such areas that it destroys nearly 30-40 per cent seedlings particularly those which are 6-8 inches high. The disease has also been reported from Uttar Pradesh by Dey (1948) and from Hyderabad by Vaheeduddin (1947).

*Symptoms:* The disease first makes its appearance on both the surfaces of the cotyledonary leaves in the form of roundish patch of dull green colour which soon spreads to the point of attachment causing the leaf to rot and hang down. The infection further spreads to the stem with the result that the seedling is killed either due to the destruction of growing point or by the collapse of stem (Plate VI-left). The true leaves of seedlings and the very young leaves of older plants may also be affected; but ordinarily not much injury is caused. The leaf spots turn yellow and then brown and concentric zones of lighter and darker brown colour are formed. The outer border is not well defined and is greenish above and brownish-grey below. The disease spots coalesce at a later stage and cover almost the entire leaf. The presence of veins, even in the mature leaves, does not obstruct the spread of the disease. The affected leaves shed prematurely. Under moist conditions, a very fine whitish haze is found on the under-surface of the leaf spots.

In case of mature plants also the disease may spread from young leaves to the stem through the petiole. When the older leaves are attacked the

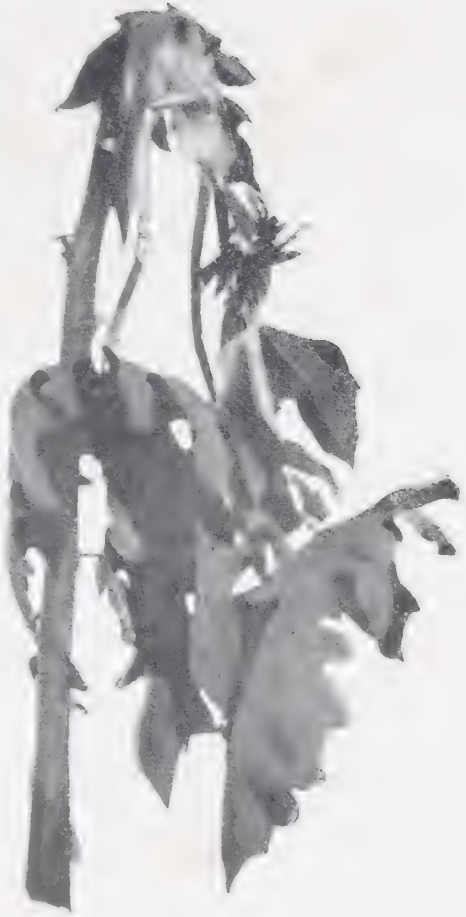
pathogen however remains localised on the leaf blade. Direct attack of stem is not very common and if it is attacked, the disease does not cause much damage. This has been considered to be due to the presence of cuticularised epidermis in older stem which resists penetration. Infection of flowers and green fruits in nature has not been reported though under laboratory conditions these parts get infected.

*Etiology:* The causal organism, *Phytophthora colocasiae* Racib., consists of inter and intra-cellular mycelium which develops inside the host tissue. After a few days' growth numerous branches emerge from the lower epidermis of the leaf generally through stomata as sporophores either singly or in twos or threes. The sporophores are slender, unbranched and of variable length from 35 to over 500$\mu$. A single colourless ovoid or roundish sporangium is borne at the tip of sporophore and measures 25—50 X 20—40$\mu$ in diameter. A ripe sporangium liberates zoospores when put in water. The number of zoospores varies from 5 to 45 in each sporangium. The zoospores germinate readily by one or rarely two germ tubes. In culture or on the inoculated fruit, the fungus forms chlamydospores which are round, thick-walled yellow bodies and measure 20 to 60$\mu$. These are formed freely during hot and dry months when sporangia are scanty and retain the power of germination for many months. Oospores have also been produced on artificial cultural media. The oospores remain viable for a long period and it is considered possible that these might serve as a source of carrying the parasite over from one crop to the next.

Secondary infection spreads rapidly through sporangia provided the weather conditions are favourable. The sporangia are easily disseminated by the wind and germinate readily on the leaves producing zoospores which penetrate by means of germ tubes either through stomata or directly and produce diseased spots within 24 hours and the next crop of sporangia appears in about two days.

The fungus also causes infection on young potato, tomato and brinjal plants and seedlings of several garden annuals. It also produces infection on the leaf of *Sesamum* and on the flower of *Sida cordifolia*. These plants might serve as collateral or alternative hosts of the fungus and help in the perpetuation of the disease. It has also been reported from New South Wales (Anon, 1953) that *P. parasitica* isolated from black shank tobacco plants attacked castor bean plants in the glass house but was only weakly parasitic.

Thomas and Ramakrishnan (1948) made detailed study on the physiological behaviour, morphological characters and the pathogenicity of *Phytoph-*



*Castor plant affected with seedling blight caused by Phytophthora parasitica*

*Leaf spot of Castor (Cercospora ricinella): Affected leaf.*

*Plate VI*

*thora* species isolated from castor, *Agave wightii* and *Artocarpus incisa*, authentic cultures of *P. parasitica*, its var. *piperina* and *P. colocasiae* and concluded that there was no significant inter-specific difference between the species mentioned above. Thus they proposed a common name of the fungus as *P. colocasiae* on the basis of nomenclatural priority.

*Control:* Regarding control measures, Butler (1918) suggested that damp and low lying localities should be avoided for sowing castor. Spraying with Bordeaux mixture at places where silk-worm is not maintained on castor will be beneficial but whether it would be economical or not requires consideration.

## Rust

The disease occurs in Bombay, Deccan districts, Coimbatore and Nagpur. It usually appears in Bombay between November and February on castor sown in June. Vaheeduddin (1947) observed that the damage caused by this disease was very severe in moist localities and at places where the disease appeared quite early. In Hyderabad the disease appears only in December when the capsule formation has already started so that little damage is done to the crop.

*Symptoms:* The disease appears in the form of rust pustules on the under-surface of the leaves. The uredopustules are often grouped in small circles and two or more may coalesce to form bigger patches. The pustules burst at a later stage exposing the powdery mass of uredospores which are orange-yellow in colour. The under-surface of the leaf is marked by the corresponding small roundish yellow spots. In severe attacks practically every leaf is densely covered with rust pustules with the result that leaves may get dried up and wither prematurely.

*Etiology:* The hyphae of the causal organism [*Melampsora ricini* (Biv.) Pass.] collect beneath the epidermis of the leaf and form a minute cushion. The uredospores arise beneath the epidermis on the tips of branched hyphae. Stout club-shaped paraphyses are also formed in the sorus. At maturity the epidermis ruptures releasing clouds of spores. The uredospores are round or elliptic, warty and orange in colour and measure 25—29 X 19—25$\mu$. They germinate by germ tube which comes out from the pores and infects fresh leaves of castor. It was observed that the rust culture could not be maintained on host plants under Delhi conditions beyond the beginning of April because of rise in temperature.

In green house tests, work done in Portugal (Noronha, 1952) proved that *Melampsora ricini* is pathogenic to *Euphorbia obtusifolia*, *E. ipecacuanha*,

*E. giniculata* and *E. marginata* besides 24 strains and varieties of *R. communis*. Isolates of *M. euphorbiae* from 5 species of *Euphorbia* including *E. peplus* failed to infect castor.

*Control:* The disease is reported to be successfully controlled by spraying the crop with sulphur but the question whether the measure is economically feasible or not requires to be considered. More concentrated efforts are necessary to evolve methods for the control of this disease. Possibility of evolving resistant varieties also requires to be explored.

### Alternaria Blight

The disease has been reported from different parts of the country from time to time by Dastur (1913), Chibber (1914), Dey (1948), Singh (1955), Vasudeva (1956) and Pawar and Patel (1957) and is assuming serious proportions in the recent years particularly in Bombay areas. In some other countries also, Alternaria leaf spot is considered to be one of the serious diseases of castor. Stevenson (1945) reported that in humid years extensive fructification of the fungus takes place on the capsules of castor plant giving black, sooty appearance which on shaking gives rise to black clouds of conidia. In some fields about 70 per cent of the plants are reported to be affected with the disease causing serious losses in yield and oil content. When the infection takes place in early stages of flower development the buds are killed and the inflorescence turns black. If the disease appears at a late stage, the flowers shed without capsule formation and in mild attack only individual flowers dry up. Stevenson (1947) reported that the height and general vigour of seedlings were reduced due to the disease which affected the yield to a considerable extent, being 870 lb. per acre as against 1098 in the healthy plot. Thomas (1949) also reported damage caused by the disease to castor in Maryland which resulted in poor seed production.

*Symptoms:* All the aerial parts of the plant, *i.e.*, stem, leaves, inflorescence and capsules are liable to be attacked. The disease first makes its appearance on the cotyledons in the form of spots and if the infection is extensive, the plants become stunted and ultimately die. The spots on the leaves are seen throughout the year and become more extensive during rainy season. These may appear on any portion of the leaf and are irregular, scattered, and have concentric rings. These are brown and later become covered with bluish-green or sooty growth. When the attack is severe the spots coalesce and form big patches resulting in premature defoliation of the plant which gradually wilts away.

The inflorescence and the capsules are also attacked and get covered partially or fully with a similar sooty growth. Two types of symptoms may be observed on the capsules. In one case the capsules, when half mature, wilt suddenly, turn brown and due to collapse of the pedicel the capsules fall or hang down. They are smaller in size and have under-developed and wrinkled seeds with little oil content. The germination of the affected seeds is also adversely affected. In other case, the attack is generally on the fully developed capsules resulting in the appearance of sunken spots on one side of the capsule which gradually enlarge to cover the whole pod with characteristic growth of the fungus. The pathogen may infect the seed if the capsule cracks.

Stem of the castor plant has also been reported to show symptoms of the disease in some of the exotic varieties.

*Etiology:* The disease is caused by *Alternaria ricini* (Yoshii) Hansford. The conidia are produced abundantly on the diseased portion under moist conditions and borne in chains on the conidiophores. The conidiophores are straight, erect or irregularly bent, solitary, sometime in fascicles and are olivaceous in colour. Singh (1955) reported the length of conidiophores to be 62 to 109$\mu$ with 3 to 8 septa while Pawar and Patel (1957) as 30 to 60$\mu$. The conidia are obclavate, light olive in colour but become darker in mass. They are segmented into 5-16 cells with transverse and longitudinal septa and measure 71·4 to 193·2$\mu$ (mean 124·27$\mu$) and 29·4 to 92.4$\mu$ (mean 61·8$\mu$) with and without beak respectively, and 12·6 to 33·6$\mu$ (mean 20·36$\mu$) in width (Singh, 1955). The beak is narrow, colourless, long and unbranched. The conidia formed in culture are usually smaller in size than those formed on the host.

The disease is carried over through the seed both externally and internally (McClellan, 1944; Stevenson, 1945: Singh 1955). It is reported that the disease causes pre and post-emergence damping off and a seedling and foliage blight when the diseased seeds are sown. The fungus is reported to infect and produce disease symptoms on *Jatropha pandurifolia* and *Bridelia hamiltoniana* in addition to its own host *Ricinus communis*.

Some of the conditions which govern the severity of the disease are reported to be the presence of a susceptible variety, high atmospheric humidity and low temperature (16-20°C).

*Control:* Practically no work has been done on the control measures of this disease; but it has been indicated that seed treatment may be useful in combating the initial phase of the disease.

### Cercospora Leaf Spot

The disease has been reported from Bihar, Uttar Pradesh and Hyderabad and is probably present in many other parts of the country. It causes considerable injury to the leaves and is the source of loss of food for the Eri-silkworm which is maintained on castor plant.

*Symptoms:* The disease appears as minute black or brown points surrounded by a pale green ring (Plate VI-Right). These spots are visible on both the surfaces of the leaf. As the spots enlarge, the centre turns pale brown and then greyish-white surrounded by a deep brown band which may be narrow and sharp or broad and diffused. The fructifications of the fungus appear as tiny black dots in the white centre. The diseased spots often occur in great numbers scattered over the leaf and are roundish when young but may become irregularly angular when mature. When the spots are close together, the intervening leaf tissue withers and large brown patches of dried leaf may result.

*Etiology:* The disease is caused by *Cercospora ricinella* Sacc. & Berl. The hyphae of the causal organism collect beneath the epidermis and form very small stomata. Clusters of conidiophores usually in groups of 10-20 emerge through any part of the leaf tissue and form the fructification of the fungus. The conidiophores are brown below and lighter towards the tip and are septate, unbranched and measure from 24 to 70 by 3 to 6·5$\mu$. The upper part of the conidiophores is characteristically knobby or flexed. The conidia are elongated, colourless, tapering above and truncated below, straight or slightly curved, multiseptate (upto 7 transverse septa) and measure upto 105 by 4 to 6·5$\mu$.

Singh (1948) reported that the spores of *C. ricinella* were commonly associated with the seed of castor but what part they play in the perpetuation of the disease is not known.

*Control:* Spraying with Bordeaux mixture or other copper fungicides may help to bring the disease under check; but where the cultures of Eri-silkworm are maintained on castor plants, spraying would not be desirable. Use of resistant varieties would be the most effective method for combating the disease.

### Phyllosticta Leaf Spot

The disease was reported by Bose and Mathur (1949) from Kanpur (U.P.) where it was reported to be prevalent on castor crop in severe form. It is usually found during rainy season.

*Symptoms :* The disease is characterised by the appearance of minute dot-like light brown spots scattered on the upper-surface of the leaf which later enlarge and transform into light brown circular lesions measuring 0·4 cm. to 1·2 cm. in diameter but these may be as big as 2·5 cm. These spots may coalesce to form irregular patches. Circular zonations of different shades of brown also appear as the spots get enlarged. The centre of the spots may become white and brittle resulting in shot holes. At a later stage successive concentric rings of black dot-like structures (pycnidia of the fungus) are formed at the margins. Within 10 to 16 days of infection the disease spots attain the maximum size but these never cross the main veinlets.

The fungus penetrates into the cells of the host, destroys the chloroplast and ultimately kills them and produces a diseased spot.

*Etiology :* The disease is caused by *Phyllosticta bosensis* Bose and Mathur. The fungus is found in the diseased portion of the host as hyaline, septate and branched mycelium which is intra-cellular. The hyphae from the dead portions of the leaf aggregate and form black elliptical pycnidia which measure 25·2 to 97·2 by 14·2 to 42·2$\mu$. The conidiophores are found inside the pycnidium usually at the base. The pycnospores are hyaline, one-celled, oblong and measure 4·32 to 10·8$\mu$ by 1·8 to 2·8$\mu$.

The spores germinate readily in water by giving out a germ tube and cause infection of the host under humid conditions. The symptoms start appearing within 3 days and typical spots with pycnidia develop within 8 to 10 days.

*Control :* The disease is reported to be brought under control by spraying the crop with 4:4:50 Bordeaux mixture or other copper fungicides. Two sprays at an interval of 15 days are said to be quite effective.

### Powdery Mildew

The disease was first recorded by Ramakrishnan and Narasimhalu (1941) in India and is reported to be prevalent during November to March at Coimbatore. It is characterised by typical mildew growth which is generally confined to the under-surface of the leaf. When the infection is severe the upper-surface is also covered by the whitish growth of the fungus. Light green patches, corresponding to the diseased areas on the under surface, are visible on the upper side especially when the leaves are held against light.

The disease is caused by *Leveillula taurica* (Lev.) Arn. [*Oidiopsis taurica* (Lev.) Salm.]. The pathogen is endophytic and consists of hyphae which

are intercellular and occupy the spongy parenchyma of the mesophyll. The haustoria penetrate into some of the parenchymatous cells. The conidiophores of the fungus are branched and usually emerge through stomata in aggregation. The conidia are hyaline, varying in shape, bear minute papilla-like projection at the broad end, measure 52-88 $\mu$ by 12-23·9 $\mu$ (mostly 67.3 by 18.7 $\mu$) and are borne singly at the tip of each branch. These germinate readily in water producing a germ tube from one end.

The fungus is also reported to produce powdery mildew disease on *Cyamopsis tetragonoloba*, *Capsicum annuum*, *Medicago sativa* and *Vinca pusilla*.

### Bacterial Leaf Spot

The disease has been reported from Bombay (Patel *et. al*, 1951) and is similar to the one occurring in Japan, Korea and Uganda.

The pathogen attacks cotyledons, leaves and veins and produces few to numerous small, round, water-soaked spots which later become angular and dark brown to jet black in colour. The spots are generally aggregated towards the tip. At a later stage the spots become irregular in shape particularly when they coalesce and areas around such spots turn pale-brown and brittle. Bacterial ooze is observed on both the sides of the leaf which is in the form of small shining beads or fine scales.

The disease is caused by *Xanthomonas ricinicola* (Elliott) Dowson which is gram negative, liquefies gelatin, hydrolyses starch, digests casein, peptonises milk, reduces litmus, produces ammonia and hydrogen sulphide and does not reduce nitrates. The optimum temperature for the growth of the bacterium and its thermal death point are 31°C and 51°C respectively.

### Other Diseases

Besides, the castor crop suffers from 'Damping off' [*Pythium aphanidermatum* (Ed.) Fitz.]; Root rot [*Macrophomina phaseoli* (Maubl.) Ashby] ; Leaf spot (*Cladosporium* sp.) ; Seed rot (*Cephalosporium curtipes* Sacc.) reported by Joshi (1954) ; leaf spot caused by *Diplodia ricinicola* Sacc. which is reported to cause considerable damage in U.P. (Anon., 1946) and Sclerotinia rot [*Botryotinia ricini* (Godfrey) Whetzel].

CHAPTER XIII

# INSECT PESTS OF CASTOR

By

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In the following pages the bionomics, biology and control of the insect pests of castor plant are described.

## 1. The Castor Semilooper, *Achoea janata* L. (Lepidoptera : Noctuidae)

This is a serious pest (Plate VII) of the oilseed crop and is distributed throughout the Indian Union, wherever castor is grown. The smooth greyish-brown caterpillars feed on the leaves and cause sometimes wholesale devastation of the crop in certain regions like the Deccan plateau.

### *Life History*

The female moth lays eggs singly on the leaves of the castor plant at night. The eggs are laid singly on both sides of the leaves. Four to six eggs have been observed on each leaf. The egg when freshly laid is round, pale green in colour and measures about 0·9 mm. in diameter. The chorion is full of ridges and furrows. The egg is convex on the upper surface and concave below. The incubation period of the egg varies from 2 to 5 days from July to September. The newly hatched caterpillar is yellowish green in colour with light brown head and thorax and measures 3·5 mm. long. The full-grown larva is dull greyish brown and measures 60 to 70 mm. long. Five distinct larval instars have been observed. The larval period lasts from 12 to 13 days in July, August and September. Pupation takes place either in the soil amidst the fallen leaves or sometimes amidst the folded leaves on the plant. The pupal period lasts from 10 to 27 days. A generation is completed in about 28 to 45 days.

### *Control Measures*

The following control measures are recommended :

(*a*) Collection and destruction of larvae in the early stages of infestation will reduce the pest population.

(*b*) Dust the infested crop with 10% DDT or BHC.

*Natural Enemies*

A number of hymenopterous parasites attack the pest during the various stages of its life-cycle. The eggs are parasitised by *Trichogramma evanescens minutum* Riley. The larvae are heavily parasitised by a braconid parasite, *Microplitis maculipennis* (Szep). Two larval parasites, one a chalcid, *Euplectrus* sp. and another a braconid, *Rhogas* sp. have also been recorded. It is very important that the dusting operations are so planned that natural enemies are not destroyed. Associated with the castor semilooper is another semilooper known as *Parlellia algira* Linn. (Lepidoptera : Noctuidae). This insect closely resembles the castor semilooper in its habits and life history and so the same control measures can be adopted to control the pest.

2. The Castor Capsule Borer, *Dichrocrocis punctiferalis* Guen. (Lepidoptera: Pyralidae)

This is another important pest of castor (Plate VIII). The caterpillars bore into shoot and seed capsules and cause extensive damage to the crop. The pest is distributed throughout the plains and the hills of the Indian Union. This has also been recorded as boring into the fruits of several horticultural crops. The larvae have also been observed infesting ginger, turmeric and cardamom. The female moths lay eggs on the tender parts of the plant. The caterpillar that hatches out bores into the shoot if the plant is young and knit the seed capsules if the plant is old. The full-grown caterpillar is stout, reddish brown in colour and measures 15 to 25 mm. long. It pupates in a silken cocoon. Though the pest is an important one we have very little information about its bionomics, life history and methods of control.

*Control Measures*

The infested shoots and seed capsules may be collected and destroyed.

3. The Castor Hairy Caterpillar, *Euproctis lunata* (Wlk.) (Lepidoptera : Lymantriidae).

The caterpillars of this pest cause serious damage to the crop by completely defoliating the leaves during the *kharif* season. When the soft foliage has been exhausted, they even turn to the bark to satisfy their insatiate appetite. This pest has been observed causing damage to fruit trees in the Punjab.

*Life History*

The female moth lays its eggs in clusters on the under-sides of leaves and covers them with pale brown hairs. The incubation period lasts from 5 to

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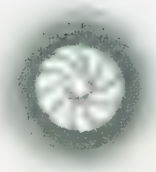

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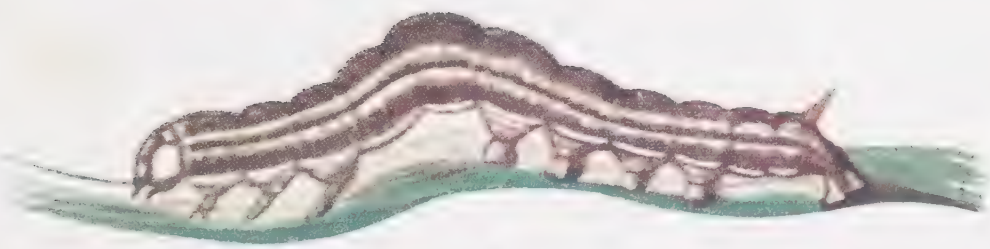

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*Plate VII*

*Fig. (1) Eggs on leaf : (2) Egg enlarged : (3) Larva : (4) Cocoon : (5) Pupa : (6) Moth.*

*Plate VIII*

*Fig. 1 Stalk and Capsule of Castor plant showing silk webbing: (2) Shoot of Castor: (3) Larva: (4) Pupa in Castor seed: (5) Pupa in cocoon: (6) Moth.*

10 days. The newly hatched larvae feed gregariously and after a few days part company and feed on the leaves independently. The larval period varies from 15 to 85 days and the pupal period 7 to 20 days. The pest is active throughout the year and several generations have been observed. The peak period of activity is August-September. As in the case of many other pests, there is a wide gap in our knowledge on the bionomics, biology and control of this pest.

*Control Measures*

The following control measures are recommended :

(*a*) In the early stages of infestation, collect the egg masses and caterpillars and destroy them.

(*b*) Dust the crop with 10% BHC or spray with 0·25% DDTW/P or emulsion.

*Natural Enemies*

One scelionid egg parasite, *Aholcus euproctiscidis* Mani and two braconid larval parasites, *Apanteles enproctisiphagus* Muzafar Ahmad and *Glyptomorpha deesae* Cameron have been recorded. There is heavy infestation by *Apanteles* and every effort should be made to conserve the parasite population in the field. Other hairy caterpillars belonging to this family like *Euproctis fraterna* Mo., *E. scintellans* also occur on castor and may be similarly treated.

4. Prodenia Litura F. (Lepidoptera : Noctuidae)

The full-grown velvety black caterpillars with yellow-green dorsal stripes and lateral white bands are familiar objects feeding not only on castor and groundnut but also on banana foliage, 'agathi', tomato etc. It also bores into the tender stems of the plant. The pest has a wide distribution throughout the Indian Union and occurs as a sporadic pest.

*Life History*

The female moth lays eggs in clusters clothed with brown hairs. The incubation period of the egg varies from 3 to 5 days. The newly hatched larvae are blackish-green in colour and feed gregariously for a short period before dispersal. They behave like cutworms as they grow and sometimes cause extensive damage to the plants at night. In view of this behaviour the pest is classified as a cutworm. The full-fed larva is velvety-black in colour and measures 35 to 40 mm. long. The larval period varies from 15 to 30

days. Pupation takes place in the soil and the pupal period varies from 7 to 15 days. Eight generations have been known to be completed during a year.

*Control Measures*

The following control measures may be adopted :

(*a*) If the area to be treated is small, collect and destroy the egg masses and caterpillars in the early stages of infestation.

(*b*) Plough up the soil so as to expose the pupae to predators and parasites.

(*c*) The crop may be sprayed with 1 lb. of lead arsenate, 1½ lb. of lime and 3½ lb. of molasses in 35 gallons of water.

(*d*) Spray with Endrin emulsion 0·075 to 0·1% according to the degree of infestation under expert supervision.

*Natural Enemies*

A large number of parasites have been bred and recorded. One ichneumonid larval parasite, *Angitia argenteopilosa* Cameron has been recorded. The braconid parasites, one larval and another egg-larval, *Apanteles prodeniae* Vier and *Chelonus* sp. have also been recorded. The pupae have been found to be parasitised by an eulophid, *Trichospilus pupivora* Ferr. The exact role of these parasites in the natural parasitism of this pest has not been studied so far.

5. The Castor Slug *Parasa lepidacram* (Lepidoptera : Limacodidae)

This pest damages the castor plant sporadically. It is most common in the southern regions of the country especially Madras and has been recorded from Ceylon also. The caterpillars are spiny and when touched, cause irritation to the skin. To begin with, they feed gregariously on the leaves of castor and later spread over to the entire plant. Besides castor, they damage tender mango leaves, *Ficus benjamini*, *Flacourtia*, pomegranate, coconut, wood apple and palmyra palm.

*Life History*

The female moth lays flax scaly eggs on the tender parts of the plant in small clusters. The full-grown caterpillar measures 15-25 mm. in length. It is bright green in colour and has interrupted blue stripes on the dorsum.

Thick short spiny hairs arise out of rows of warts on the body. It moves like a slug. Pupation takes place in a hard greyish cocoon on castor stem or the trunks of its other host plants. The pupal period lasts from three to five weeks or longer.

*Control Measures*

The pest should be kept in check by picking the gregarious caterpillars and the cocoons which are found in numbers on tree trunks and destroying them in water with a film of kerosene.

6. The Castor Mealy Wing, *Trialeurodes ricini* Misra (Homoptera : Aleurodidae)

The castor white-fly is a pest of castor in some regions of our country. It is more commonly found in Bihar, Bombay, Andhra and Madras. Sometimes the damage caused by this pest to castor crop is serious. The other plants infested are *chiku* (*Sapota*) and *Breynia* sp.

*Life History*

The adult fly has white wings, yellow body and pale white legs and antennae. It is a tiny insect a little less than a millimetre in length. The female lays shining white long eggs in small clusters or scattered about on the underside of tender leaves. The eggs hatch into nymphs which settle on the leaves and along with the adults suck the sap from the leaves. This makes the leaves appear sickly. Both the nymphs and the puparia are yellowish in colour.

*Control Measures*

The damage of white flies may be kept down by spraying the infested plants with 0·05% malathion.

Predaceous spiders, coccinellid larvae and adults feed on the pest and a chalcid parasite parasitises the puparia. These should be conserved to keep the incidence of the pest in check.

7. The Castor Jassid, *Empoasca flavescens* Fb. (Homoptera : Jassidae)

The castor jassid occurs on castor as a minor pest. It has been recorded from Bihar, Madras and Assam. Outside India it has been recorded in Burma. Besides castor it infests tea and probably some other plants.

*Life History*

It is a small green jassid. Both the nymphs and the adults suck the juice of the leaves and tender stems.

*Control Measures*

The jassid should be controlled by dusting the plants with about 3% DDT before the formation of capsules.

8. The Red Mite, *Tetranychus telarius* L. (Acarina : Tetranychidae)

Colonies of the red mites occur on castor leaves and desap them. The leaves lose their healthy green colour and turn grey. We know very little about the bionomics and biology of this mite. The damage by the mite however can be kept down by dusting with sulphur at the rate of about 20 lbs. per acre.

## BIBLIOGRAPHY


1. ACHAYA, K. T. and SALETORE, S. A. (1953) *J. Sci. Ind. Res. (India).* **12B**: 471.

2. AGGARWAL, J. S., CHOUDHARY, H. D., MUKERJI, S. N., VERMAN, L. C. *Bull. Indian Ind. Res.* Nos. **8** and **20**.

3. ANDERSON, P. J. (1927) Check list of diseases of economic plants in the U.S. *Bull. Dept. Agri. U.S.A :* **1366**: 91.

4. ARCHIBALD, R. G. (1927) The Castor oil plant black rot in the Gaiza. *Trop. Agri. Trinidad.* **4**(**No. 7**) : 124-125.

5. BAILEY, L. H. (1924) Manual of cultivated plants. Macmilan and Co., New York. pp 456.

6. BHAVANISHANKER RAO and THANDAVARAYAN (1954)—A note on an abnormality in the fruits of castor *Madras. J. Agri.* **41**: 228.

7. ————————————(1954)—Occurrance of multilocular fruit in *Ricinus communis—Madras J. Agri.* **41**:329.

8. BHAT, R. V. and JASPAL, N. S. (1951) *Indian Forest Leaflet No. 124* 1954 *Indian Forest Bulletin* **No. 176 ;** 1956 *Indian Pulp and Paper. ;* **10** *:* 481.

9. BHATE, S. R. and SHENOLIKAR, G. S. (1944) *Hyderabad Sci. Ind. Res. Bd.,* Dept. Commerce Ind., H. E. H. the Nizam's Government., Hyderabad Bull. No. **11**.

10. BARKOVASKI, V. E. and PODYURSAKAJA, F. P. (1937-38) Breeding work with Castor oil. *Plant Br. Abs.* **8**(**1**) *:* 64.

11. BLARINGTON LOUIS. (1947) A new variety of Ricinus etc. *Compt. Rend. Acad. Sci. Paris* **225**(**6**) 327.

12. BLUMER. *German Pat.* 227,993.

13. BOSE S. K. and MATHUR, S.C.A. (1949) New leaf spot disease of Castor. *Curr Sci.* **18** *:* 210:—211.

14. BUTLER, E. J. (1918) Fungi and diseases in plants. Thacker Spink Co., Calcutta and Simla.

15. ———————————and BISBY, G. R. (1931) The Fungi of India *Scientific monograph* **No. 1** Imp. Coun. of Agri. Res.

16. CHANDRASEKHARAN, S. N. and DANIEL SUNDARAJ, D. A. (1946) Note on the inflorescence of *Ricinus communis. Jour. Ind. Bot. Soc.* **25** *:* 103.

17. CHITTENDEN, A. E. and COOMBER, H. E. (1950) Castor stems from Ceylon. *Bull. Imp. Inst. Gr. Britain.* **46**(**2**/**4**) *:* 223-227. 1948. *Bio. Abs.* **24**(**4**) *:* 10373. 1950.

18. CHONARD, P. (1950) *Bull. Tech. Infor. Ingen. Sern. Agri.* **28**/**29** *:*273-276. 1948. *Pl. Br. Abs.* **No. 1 :** Jan 1, 1950.

19. CIFERRI, R. and GONGALEY FROGOOS. (1926) Parasitic and Saprophytic Fungi of the Dominion Republic. *Rev. Appl. Myco.* **5 :** 558-584.

20. CLASSEN, CARL E. and HOFFMAN ALBERT. (1950) The inheritance of pistillate character in castor and its possible utilisation in the production of commercial hybrid seed. *Jour. Amec. Soc. Agr.* **42 :** 79-82.

21. COLBETH, J. M. (1951) Castor beans paying crop for peace and war. *Chem. Dig.* **10** (**12**) *:* 47.

22. CONTINKE, G. (1918) Une nouvelle variete de Ricini. *Bull. Soc. Portuguise. Soc. Nat.* **8** *:* 82-83.

23. CURZI, M. (1933) *Cercosporina ricinella* Boll. R. Staz. *Pat Veg.* **12**: 149-162. 1932. *Rev. of Applied Mycology* **12** : 246-247.

24. DARLINGTON, C. D., and WYLIE—(1956)—Chromosome atlas of cultivated plants.

25. DASTUR, J. F. (1913) *Phytophthora parasitica* Nov. Spe., A new disease of the castor oil plant *Mem. Dept. Agri India. Bot. Ser.* **5** : 177-231

26. De CANDOLLE. (1860) *Prodromous Systematis Naturalis regni vegetabilis.* **17** : 1016. Paris.

27. DEIGHTON F. (1928) Ann. Rep. of land of forest Department. Mycological section serima leave for the year 1926. *Rev. of Appl. Mycology.* **7** : 304-305

28. DELAPLACE R. (1939) *Rend.* **208** : 515.

29. De Menezes. O.B.O. brote oxilar etc.

30. DHARAMPAL SINGH. (1954) *Jour. Dept. of Agri. Agri. Engineering, Animal husbandry and Cane Development,* U. P. **5** : 4

31. DIONIGI, A. (1951) Bio. Abs. **25** : 25028

32. DOLE, K. K. (1951) *Proc. Symposium on Indian oils and fats and their utilisation.* National Chemical Lab., Poona. p. 192.

33.————————and KESKAR, V. R. (1954) *Proc. 41st Indian Science Congress.* **Part 3.** p. 97.

34. DOMINGO, W. E. (1944) Amount of natural crossing in the castor oil plant. *Jour. Amer. Soc. Agro.* **36** : 360-361.

35.————————(1945) Flowerless castor bean plants. *Jour. Heredity.* **36** : 116-120.

36.————————and CROOKS D. M. (1945) Investigations with castor bean plants. *Jour. Amer. Agron. Amer.* **37**(**9**) : 750-762.

37.————————(1945) Investigations with castor bean. *Jour. Amer. Soc. Agron.* **37** : 812-820.

38.————————(1945) Investigations with castor bean plant. *Jour. Amer. Soc. Agron.* **37** : 910-915.

39.————————(1948) Castor seed. Oil crops with new look. *Chem. Dig.* **7** : 12-13.

40.————————(1951) Castor beans—a truly chemurgic crop. *Chem. Dig.* **10**(**3**) : 7-8.

41.————————(1954) Oil percentage through test weight. *Seed world.* **57**(**4**) : 8-9.

42. DU PONT DE NEMOURS, (1946). *U.S. Pats.* 2,402,530 ; 2,402,541 ; 2,402,530.

43. ECKEY, E. W. (1954) Vegetable fats and oils. A C. S. Monograph series, No. 123, Reinhold Publishing Corp., New York. pp. 594.

44. EDELSTEIN, E. (1940) *Paint oil Chem. Rev.* **102** : 10.

45. ERCOLE, Q. (1924) The cultivation of castor oil plant. *Agri. Gaz.* N. S. W. **17**: 173.

46. FIERO GEORGE, W. and TED A. LOOMIS. (1945) Hydrogenated castor oil as an ointment base. *Jour. Amer. Pharmac. Assoc.* Ed. **34**(**8**) : 218 (*Bio. Abs.* **19** : **10** : 22754. 1945).

47. FLETCHER, T. B. (1914) South Indian Insects.

48.————————(1917) *Proc. Soc. Entomo. Meeting,* Pusa. pp. 86-89.

49. FLUCKIGER and HANBURY. Pharmacography 567. Refer Watts *Dictionary of Economic Products of India.*

50. GHOSH, M. N. (1924) Oil content of castor seed as affected by climate and other conditions *Agri. Jour. India* **19** : 81-84.

51. GODFREY, G. H. (1919) *Sclerotinia ricini* Nova Sp. Parasitic on castor bean. *Phytopath.* **9** : 565-567.

52.————————(1923) Grey mould of castor bean. *Jour. Agri. Res.* **23** : 679-715.

53. GREENHEL P. W. (1940) *American Ink Maker.* **18** : 20.

54. GUPTA, S. S. and AGGARWAL, J. S. (1952) *Jour. Sci. Ind. Res. (India).* **11 B** : 303.

55.————————HILDITCH, T. P., and RILEY, J. P. (1951) *Jour. Sci Food Agri.* **2** : 245.

56. HADLEY, C. MAINDERS and MELVIN D. JONES. (1950) Pollen-shedding and dispersal in castor plant *Ricinus communis* L. *Agro. Jour.* **42** : 206-209.

57. HALEY D. E. and LYMAN J. F. (1921) *Jour. Amer. Chem. Soc.* **43** : 2664.

58. HARGRAVES, G. H. and OWEN, L. N. (1947) *Jour. Chem. Soc.* p. 753.

59. HARLAND, S. C. Notes on castor oil in the West Indies. *Agri. News.* Barbados. **No. 416** pp. 100.

60————————(1920) Inheritance in *Ricinus communis* L. Part I. *Jour Gene.* **10** ; 207-218.

61.————————(1922) Inheritance in *Ricinus communis* L. Part II. *Jour. Gen.* **12** : 251-253.

62.————————(1928) The genetics of *Ricinus communis* L. *Biblie Genetica.* **4** : 171-177.

63. HILTERBRANDT, V. M. (1935) The plant resources of the world as initial material in plant breeding. The Castor Plant 55-70. *Lenin. Aca. Agri. Sci. Inst. Plant Industry,* Mascow and Leningrad. **No. 6**

64. HILL, ALBERT F. (1952) Economic Botany. McGraw Hill Book Co., New York.

65. HOOKER, J. D. (1890) Flora of British India, **Vol. V.** L. Reeve and Co. London.

66. ILJIRA, A. I. (1951) The initiation of the primordia of the central inflorescence in castor oil plant. *Agrobiology.* **190(5)** : 146-4-8. (*Plant. Breed Abs.* **21(3)** : 2077).

67. ISIKAWA, S., TOSIMITU, T., MIYATA, A., ARAKI, Z. and SOMENO, R., (1939). *Sci. Reports Tokyo Bunraika Daigaku,* **A-3**, 273 ; *Chem. Abstr.* (1940) **34** : 3240.

68. JACCINI, G. (1949) *Olearia.* **3** : 521; *Chem. Abstr.* (1950) **44** : 1414.

69. JOHN C. M. and RAO, U. N. (1942) Perennial or tree castor. *Mad. Agr. Jour.* **30(4)** : 109.

70. JOSHI, W. V. (1926) Some variations in the inflorescence of the castor plant. *Poona Agri. College Magazine.* **18(1)** : 26-29.

71. JONES, H. (1951) *Chimia.* **8** : 169.

72. KAMATH, N R and KULKARNI R. K. (1950) *Jour. Sci. Ind. Res.* (India). **9B** : 289.

73. KATAYAMA, Y. (1952) The progeny of the female individuals in the castor bean. *Japan Jour. Gen.* **23** : **19**. 1948 (*Pl. Br. Abs.* **22 No. 3**) : 2157).

74. KAPPELMIER, C. P. A., VAN GOOR, W. A. and R. VAN HELDEN. (1948) *Paint Tech.* **13** : 261.

75. KAVASINA Mme E. S. (1928) Pre. Rep. of survey diseases of medicinal plants in North Caucasus. *Rev. Appl. Myco.* **7** : 763-765.

76. KAUFMAN, H. P. and Funke, F. (1938) *Fette U. Seifen.* **45** : 255.

77. KNOWLES, P. F. (1950) Castor bean studies for potential value as oil crop for California. *California Agri.* **3(3)** : 13-14. (*Bio. Abs.* **24(6)** : 16580).

78. KODRAS, R., WHITEHAIR, C. K. and Mac VICKAR, R. (1949) *Jour. Amer. Oil. Chem. Soc.* **26** : 641.

79. KRISHNAMURTHY, T. S. (1951) Improved varieties of oilseeds—Castor. *Indian Farming.* **1**: 18-20.

80. KRUG, C. A., MENDES, P. T. and SAUSA, O. F. De. (1944) quoted from *Plant Breeding Abstracts* **14**(**3**) : 234

81. KUMAR, L. S. S. (1922) Effect of Castor cake manuring on chasi *Agri Jour. India* **18**: 307-308

82. KURITA, M. (1952) Secondary association of chromosomes in the castor oil plant. *Japan Jour. Gen.* **21** : **63** 1946. (*Pl. Br. Abs.* **22**(**1**).)

83. LANE, F.W. (1952) *U. S. Pat.* 2,580,931.

84. LEON, J. De. (1949) The castor oil plant, its cultivation in Israel. *Bot. Soc. Agric. Bahia.* **46. No. 5** (*Pl. Br. Abs.* **21** : **1** : 532).

85. LEGGIERI L. (1948) Races of *sanguineus* obtained by selection. *Ann. Fac. Agr. Partici Univ.* Napoli. **15** : 175-186. (*Pl. Br. Abs.* **18**(**2**) : 345).

86. LEWKOWITSCH, J. (1914) Chemical Technology and Analysis of Oils, Fats and Waxes. Macmillan and Co. London. 5th Edition. **Vol. II**. p. 399.

87. LILLEY, H. S. and CARTER, R. J. (1952) *Jour. Amer. Oil. Chem. Assn.* **35** : 87.

88. LONGENECKER, H. E. and HALEY, D. E. (1935) *Jour. Amer. Chem. Soc.* **57** : 2019.

89. MAHESHWARI, P. (1950) Introduction to embryology of angiosperms. McGraw Hill Co., New York

90. MASUR, N. G. (1933) Castor Breeding in Bombay Presidency. *Agriculture and Livestock in India.* **3**(**2**) : 125-143.

91. MANDLEKAR, M. R., MEHTA, T. N., PAREKH, V. M. and THOSAR, V. B. (1946) and *Jour. Sci. Ind. Res.* (*India*). **5B** : 45. *Jour. Indian Chem. Soc.* (Ind. News Ed.) 1947. **10** : 1.

92. McCLELLAN, W. D. (1944) A seedling blight of castor bean. *Phytopath.* **34** : 223-229.

93. MEINDERS, H. C. and JONES, Melvin D. (1950) Pollen-shedding and dispersal in castor plant *Ricinus communis* L. *Agro. Jour* **42** : 206-209.

94. MISRA, C. S. (1924) *Proc. Fifth Entomological meeting.* Pusa. p. 131-132.

95. NARAIN ANUBHAVA (1951) Mutants in castor oil plant. *Science and Culture.* **16** : 484-485.

96. ———————(1952) Bloom character in castor oil plant, *Ricinus communis* L. *Curr Sci.* **21**(**6**): 166.

97. ———————(1953) Artificial production of tetraploids in *Ricinus communis* L. *Curr. Sci.* **22**(**9**) : 268-269.

98. NIZAMUDDIN H. and KULKARNI B. S. (1953) *Jour. Sci. Ind. Res.* (*India*) : **12B** 390.

99. ———————(1953) *Paintindia.* **3**: 75.

100. OKABE N. (1933) Bacterial diseases of plants occurring in Formosa. *Jour. of Sec. Trop. Agri.* (**4**) 470-483. 1932. From *Rev. of Appl. Mycology.* **12** : 554.

101. PATWARDHAN G. W. (1931) A preliminary note on inheritance of castors. *Jour. Ind. Bot Soc.* **10**: 100-109.

102. PEAT J. E. (1926) Genetic studies in *Ricinus communis* L. *Jour. Genetics.* **19**: 373-389.

103. PENTFOUND W. T. (1932) The anatomy of the castor bean as conditioned by light intensity and soil moisture. *Am. J. Bot.* **19**: 538-546.

104. POPOVA G.M. (1930) Castor oil plant. *Lenin Acad. Agri. Sci. Inst. Appl. Bot. and New Culture* Leningrad. p. 63. (from *Plant Breeding Abstracts*).

105. ——————————(1926) The castor bean in Central Asia. *Bull. Appl. Bot.* **4**: 145-240.

106. PRIEST G. W. and J. D. VON MIKUSCH (1940) *Ind. Eng. Chem.* **32**: 1314.

107. PRISMINA (Z.D.) (1928-29) The biochemical variability of the seeds of the castor oil plant independent on geographical factors. *Bull. Appl. Bot.* Leningrad. **21**(**No. 4**): 427-436.

108. RAMKRISHNAN T. S. and NARASIMHALU I. L. (1941) A new host—*Ricinus communis* L. *Curr. Sci.* **10**: 211-212.

109. RAO A. S. (1952) A gall-midge (*Itonididae*-Diptera) pest of castor in India. *Curr. Sci.* **21**: 347-348.

110. RAO N. V. S. (1946) A note on the chemical composition of castor beans. *Proc. Ind. Aca. Sci. Sect-A.* **21**(**3**): 123-125. 1945. (*Pl. Br. Abs.* **20**(**1**): 1655).

111. Reichert I. (1945) Stem blight of castor bean plant. *Palestine Jour. Bot. Sec.* R **31**: 269-272, 1940. (*Bio. Abs.* **19**(**10**): 22851.)

112. RENDLE A. B. (1925) The classification of flowering plants **Vol. II.** Dicotyledons 261-264. Cambridge University Press.

113. REYNOLDS M. E. (1941)—Development of the vascular net work in the node of the *Ricinus communis—Am. Jr. Bot.* **28**: 728.

114. REYNOLDS M. E. (1942)—Development of the node in *Ricinus communis—Bot. Gaz.* **104**: 167-170.

115. RICCHARIA R. H. (1937) A note on the Cytogenetics of *Ricinus communis* L. *Ind. Jour. Agri. Sci.* **7**(**5**): 707-711.

116. ROSS H. (1918) Castor Oil. *Agro. Gaz. Mem. South Wales.* **29**(**No. 12**): 879-884.

117. SAVULESCU T. and RAYSS. (1936) *Rev. Appl. Mycol.* **15** : 683.

118. SCHMIDT. *Brit. Pat.* 8,245.

119. SCHWARTZ A. M. and PERRY J. W. (1949) Surface Active Agents. Interscience Publishers, New York. p. 51.

120. SCOTT, MURRAY, F and SHARASMITH HELEN M—(1933) The transition region in the seedlings of *Ricinus communis*—A physiological interpretation—*Am. J. Bot.* **20**: 176.

121. SCOTT F. M. (1937) Differentiation of the spiral vessels in *Ricinus communis—Bot. Gaz.* **99**: 69-79.

122. ——————————(1941) Distribution of Calcium oxalate crystals in relation to tissue differentiation and presence of other ergastic substances—*Bot. Gaz.* **103**: 225-246.

123. SCULLY N. J. and DOMINGO W. E. (1946) Effect of duration and intensity of light upon flowering in several varieties and hybrids of castor bean. *Bot. Gaz.* **108**: 556-570.

124. SESHADRI C. R. and NARAYANA G. V. (1951) Annual Report of the Agri. Res. Stn. Tindivanam 1947-48. (*Pl. Br. Abs.* **21**(**4**): 2441.)

125. SESHADRI, C. R. and VARISAI MUHAMMAD—(1951) Study of inheritance of certain characters in castor—Proceedings of the First Scientific Workers' Conference, Agricultural College and Research Institute, Coimbatore (Madras).

126. ——————————(1952) Maintenance of purity and vigour in castor—Proceedings of the 2nd Scientific Workers' Conference, Agricultural College and Research Institute, Coimbatore, (Madras).

127. SETHI R. L. (1931) observations on Castor oil plant, *Ricinus communis* L. in U.P. *Agri. and Livestock in India.* **1**(**3**): 243-262.

128. SCHEIBER J. (1931) *German Pat.* 513, 540.

129. SHAW W. R. (1902) The improvement of the castor plant. *Oklahoma Agri. Expt. St. Bull.* (**No. 54**) :

130. SHIFRISS (1956) Sex instability in *Ricinus communis—Genetics* **41**: 265-279.

131. SIMINSKII N. K. (1949) A new variety of castor oil plant for Ukraine. *Pl. Br. Abs.* **19**(**3**): 615.

132. SIVASAMBAN M. A., SALETORE S. A., and ZAHEER S. H. (1955) *Paintindia.* **5**: 25.

133. ——————(1954) *Jour. Sci. Ind. Res* (*India*). **13B** : 1.

134. SISLEY J. P. (1952) Translated by P. J. Wood 'Encyclopaedia of Surface Active Agents' Chem. Publ. Co., New York. p. 63.

135. SMITH E. F. and GODFREY G. H. (1921) Bacterial wilt of castor bean. *Jour. Agri. Res.* **21**(**No. 4**): 255-263. **13**.

136. SOCIETE ORGANICO (1949) *Fr. Pat.* 952, 985. *Chem. Abst.* (1951) **45**: 7586.

137. SREENIVASAN B., KAMATH N. R. and KANE J. G. (1956) *Jour. Amer. Oil Chem. Soc.* **33**: 61.

138. STEVENS H. E. (1918) Grey mould of castor beans. *Fla. Growers.* **18**(**8**): **6**:

139. STEVENSON E. C. (1945) *Alternaria ricini* (Yoshii) Hansford the cause of serious disease of castor bean plant in the United States. *Phytopath.* **35**: 249-256.

140. STEVENSON J. A. (1926) Foreign Plant Diseases. Dept. of Agri. U.S.A. 155-156.

141. STOCKHAUSEN. *German Pat.* 113, 433.

142. STOCKBERGER W. W. (1926) Castor beans. Kansas State Dept. Agri.

143. SUBBA RAO T. V. (1952) *Proc. Symposium on Paints and Varnishes.* National Chemical Lab. Poona. p. 31.

144. ——————and RAO B. L. (1953) Castor Oil as raw material for chemical industries. *Oils and Oilseeds Jour.* **5**(**10**,**11**,**12**): 61-64.

145. TARTAKOVSKII M. S. (1946) Obtaining albumen from castor bean. *Jour. Appl. Chem. Leningrad.* **17**(**4**/**5**): 274-281. 1944. (*Bio. Abs.* **20**: **1**: 1502.)

146. TANBHENBANS J. J. and EZEKIEL W. N. (1936) A rating of plants with response to their relative resistance or susceptibility to *phymatotrichum* root rot. *Texas. Agri. Expt. Stn. Bull.* **527**:

147. TAYLOR C. S. (1921) Experiments with castor seed conducted at Sabour. *Agri. Jour. of India.* **16**: 146-151.

148. TURNER FRED. (1892) New Commercial crop for New South Wales. The cultivation of *Ricinus communis* L. *Agri. Gaz. New South Wales.* **3**: 150-151.

149. UFER H. (1932) *U. S. Pat.* 1,892,258.

150. VALLETTE G. and SALVANET R. (1936) *Bull. Sci. Pharmacol.* **43**: 289, 696.

151. VERMA J. P. and AGGARWAL J. S. (1949) *Jour. Sci. Ind. Res.* (*India*). **8B**: 183.

152. WATT GEORGE. (1892) A Dictionary of Economic Products of India. **Vol. VI.** Part 1: 506-557.

153. ——————(1908) The commercial products of India. John Murray, London. Pp.915-923

154. ——————(1918) The Castor seed. *Bull Imp. Inst.* **16** (**No. 1**): 250-251.

155. ——————(1919) Castor seed from cyprus. *Bull. Imp. Inst.* **16** (**No. 4**): 492-493.

156. ——————(1919) Castor seed from isle of Pimus. *Bull. Imp. Inst.* **17** (**No. 1**):

157. ————————(1918) Cultivation of castor in Ceylon. *Trop. Agri.* **51** (**No. 5**): 297-301.

158. ————————(1927) The Eri or Castor silk worm. *Trop. Agri.* **68**: 162-165.

159. WEIBEL R. O. (1944) Effect of seed treatment on Castor bean. *Jour. Amer. Soc. Agro.* **36**: 953-954.

160. WEIBEL R. O. (1948) The Castor Oil Plant in the United States. *Eco. Bot.* **2**(**3**): 373-383.

161. ————————and BURLISON W. L. (1947) Castor beans. *Eco. Bot.* **1**: 116.

162. WEIBEL R. O. and WOODWORTH C. M. (1946) Use of the natural crossing plot in making castor bean hybrids. *Jour. Amer. Soc. Agro.* **38**(**6**): 563.

163. WILSON R. (1948) *Jour. Oil Col. Chem. Assn.* **31**: 41.

164. WHITE ORLAND E. (1918) Breeding new castor beans. *Jour. Hered.* **9**: 195-200.

165. ————————(1918) Inheritance studies on castor beans. *Brooklyn Bot. Garden Mem.* **1**: 513-521.

166. ————————(1920) Notes on castor seed cultivation. *Trop. Agri.* Peradeniya. **62**.

167. ————————(1922) Selection on castor. *Trop. Agri. Peradeniya.* **58**: 382-383.

168. ————————(1920) Some insect pests of the castor oil plant. *Agri. News.* **19** (**No. 470**):

169. WILLIAMS K. A. (1950) Oils, Fats and Fatty Acids, 3rd Edition. J. A. Churchill, Ltd., London.

GENERAL REFERENCES

170. Annual Reports of the All-India Castor Improvement Scheme, Hyderabad-Deccan, for the years 1935-36 to 1949-50 inclusive. These reports have been submitted to the Indian Central Oilseeds Committee.

171. Castor bean. 63rd Annual Report of the Agri. Expt. Stn. Nebraska, U.S.A. College of Agriculture. 1950, PP. 162. *Pl. Br. Abs.* **21.4**: 2470. (1951).

172. Hybrid Castor Plants possible (1951) *Pl. Br. Abs.* **21.2**: 1269.

173. Improved strains of major oilseeds in India. Oilseeds series No. 16. Issued by the Indian Central Oilseeds Committee.

174. Indian Oilseeds Statistics. Issued by the Economic and Statistics Adviser to the Government of India. 1950.

175. Indian Oilseeds Journal—(1957) **1**: 5.

176. Madras Agricultural Station Reports—1931-32, page 203. Superintendent, Government Press, Madras.

177. Madras Agricultural Station Reports—1934-35, page 218. Superintendent, Government Press, Madras.

178. Madras Agricultural Station Reports—1941-42, page 255. Superintendent, Government Press, Madras.

179. Report on the marketing of castor in Hyderabad State. Published by the Marketing Dept. of Hyderabad Government 1947.

180. Oil and Soap. (1941) **18**: 194.

181. The work of the General Board for promotion of Agriculture in 1949. *Bot. Produc. Fomento Agri.* **2.16**: 35-68.1950. *Pl. Br. Abs.* **21.3**: 1694. (1951).

182. Vegetable oils and oilseeds—1956—Commonwealth Economic Committee—Review 1955.

183. Agricultural Marketing in India, 1950. Published by the Government of India.

184. Year Books of Agriculture. U.S. Dept. of Agri. Washington.

## BIBLIOGRAPHY

(To Chapter XII)


1. ANON. (1946) Scheme for Researches on the pests and diseases of *til* and other oilseed crops, U.P. Summary of the annual report for the period 1st July, 1945 to 30th June, 1946.

2. ANON. (1953) Plant Disease survey for the twelve months ending 30th June, 1952.
Twenty-second Annual report N.S.W.D. Department of Agriculture Biological Branch. Division of Science Services. 47 pp., 1 map (1953 mimeograph).

3. BOSE, S. K. & MATHUR, S. C. (1949) A new leaf spot disease of castor (*Ricinus communis* L.). *Curr. Sci. 18* : pp. 210-211.

4. BUTLER, E. J. (1918) Fungi and Diseases in Plant. Thacker, Spink & Co., Calcutta.

5. CHIBBER, H. M. (1914) A list of diseases of economic plants occurring in the Bombay Presidency. *Bull. Dept. Agr.* Bombay, *65* : p. 17.

6. DASTUR, J. F. (1913) On *Phytophthora parasitica* nov. species, a new disease of castor oil plant. *Mem. Dep. Agric. Indi. Bot. Ser. 5*, pp. 177-231.

7. DASTUR, J. F. (1947) Report of the Head of the Division of Mycology and Plant Pathology. *Sci. Rep. Agric. Res. Inst.*, New Delhi, 1946-47. pp. 109-117.

8. DEY, P. K. (1948) Plant Pathology. *Adm. Rep. Agric. Dep.* U.P. 1945-46, pp. 43-46.

9. JOSHI, N. C. (1954) Rotting of castor seeds by *Cephalosporium curtipas* Sacc. *Sci. & Cult. 20* : pp. 248-249.

10. McCLELLAN, Kl. D. (1944) A seedling blight of castor bean (*Ricinus communis*). *Phytopathology, 34* : pp. 223-229.

11. NORONHA, E. DeA. (1952) Contribution to the study of *Melampsora ricini*. *Agron lusit, 14* : pp. 229-247. (English Summary).

12. PATEL, M. K. KULKARNI, Y. S. & DHANDE, G. M. (1951) Bacterial leaf spot of castor. *Curr. Sci. 20* : p. 20.

13. PAWAR, V. H. & PATEL, M. K. (1957) Alternaria leaf spot of *Ricinus communis* L. *Indian Phytopathology, 10* : pp. 110-114.

14. RAMAKRISHNAN, T. S. & NARASIMHALU, I. L. (1941) A new host *Ricinus communis* for *Leveillula taurica* (Lev.) Arn. (*Oidiopsis taurcia* (Lev.) Salm.) *Curr. Sci. 10* : pp. 211-212.

15. SINGH, R. S. (1955) Alternaria blight of castor plants. *J. Indian Bot. Soc. 34* : pp. 130-139.

16. SINGH, U. B. (1948) Phytopathological examination of seeds by Ulster method. *Curr. 17* : pp. 266-267.

17. STEVENSON, E. C. (1945) *Alternaria ricini* (Yoshii) Hansford : The cause of a serious disease of the castor bean plant (*Ricinus communis* L.) in the United States. *Phytopathology, 35* : pp. 249-256.

18. STEVENSON, E. C. (1947) The effect of seedling diseases of castor beans on the subsequent plant development and yield. *Phytopathology 37*, pp. 184-188.

19. THOMAS, K. M. & RAMAKRISHNAN, T. S. (1948) Studies in the genus *Phytophthora*. II. *Proc. Indian Acad. Sci.* Sect. B. *27*, 3, pp. 55-73.

20. THOMAS, C. A. (1949) Observations on diseases of some special crops. *Plant Dis. Reptr. 33* : pp. 453-454.

21. VAHEEDUDDIN, S. (1947) Indian Council of Agricultural Research. Scheme for research on diseases of castor from 1943 to 1947.

22. VASUDEVA, R. S. (1956) Overseas News : News from India *Common. Phytopath. News, 2* : pp. 25-29.

(To Chapter III)

1. FLETCHER, T. B. (1914) Some South Indian Insects and other animals of importance. pp. 377, 410, 497.

2. LEFROY, H. M. (1907) *Mem. Dept. Agri. Ent.* I : 171, 211.

3. IBID. (1908-12) *Mem. Dept. Agri. Ent.* II : 59-77, 79-93.

4. QADIRUDIN. M. (1946) *Indian J. Ent.*. 8(1) : 111-115.

5. REPORTS (1917) (1919) (1921) (1923) Report of the proceedings of the 2nd to 5th Entomological meetings.

6. AYYAR, RAMAKRISHNA T. V. (1940) Hand book of Economic Entomology for South India. pp. 221-222.

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